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International Health Exhibition,
LONDON, 1884.

WATER SUPPLY
AND
DISTRIBUTION.

CONFERENCES BY THE SOCIETY OF ARTS ON
THURSDAY AND FRIDAY, JULY 24 AND 25.

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International Health Exhibition,
LONDON, 1884.

WATER SUPPLY AND DISTRIBUTION.

CONFERENCES ON THURSDAY AND FRIDAY, JULY 24 AND 25, 1884.

Sir FREDERICK ABEL, C.B., D.C.L., F.R.S., in the chair.

THE CHAIRMAN, in commencing the proceedings, said the active interest displayed by his Royal Highness, the President of the Society of Arts, on this subject, had led the Council to hope that it might have been in his power to open the proceedings ; indeed, at one time, there was no doubt that this Conference would have been the opening one of the series arranged by the Executive Council of the Health Exhibition, and that his Royal Highness would have presided, at any rate, over a portion of the proceedings, when that unexpected calamity occurred which had so deeply afflicted the Royal Family and the nation. The fact that even quite recently the Prince had fixed the present date for this Conference was an indication that, had it been possible, he would have marked his sense of its importance by attending at the opening. In 1878, his Royal Highness addressed a letter to the Council of the Society of Arts, calling attention to the importance of the subject of water supply ; pointing out that whereas various large towns were at that time incurring heavy expenditure to improve their water supply, smaller towns, and particularly villages, were left to shift for themselves ; and suggesting that it might be desirable to discuss fully the question how far it might be possible to apply the great natural sources of water supply according to some national comprehensive scheme. The Council of the Society, acting on that suggestion, issued inquiries and invitations for papers, and received more than twenty papers in response, some written by men of eminence who had devoted a great deal of attention to this subject. Those papers, and the topics arising out of them, were very carefully discussed, and the general conclusion arrived at was that local conditions and circumstances presented such very considerable variations that it appeared impossible to devise any comprehensive national scheme for the supply of water to communities. But a resolution was passed that it was desirable to memorialise the Government to appoint a small permanent Commission to collect facts connected with the water supply throughout the kingdom, in order to utilise the natural resources, as indicated by his Royal Highness, according to some general system for the benefit of the country as a whole. That suggestion was not acted upon, but, nevertheless, the discussion which took place in 1878 had been fruitful of beneficial results, and it was quite certain that the subject of improved water supply had made an important advance since that time. The influence of polluted water in promoting the spread of epidemics had become more thoroughly understood and recognised, and the mischievous effects of using water derived from surface wells, and from the careless storage of water in houses, arising out of intermittent supply and other circumstances, had received much public attention; but there could be no doubt that many points bearing upon the supply of wholesome water still required further elucidation. Many interesting discussions connected with one branch or another of this subject had taken place since 1878, and probably none were more interesting than those connected with the questions as to what constituted a good water for drinking and domestic purposes, and how a sufficient quantity might be ensured. It was scarcely necessary to remind the audience that amongst the most intelligent men who had given attention to this subject there had existed, and still remained, diversities of opinion on some important points more especially connected with the question of how the purity of water was affected, and how it was re-established if the water were once polluted. Thus some authorities had maintained that no river which had been in any way polluted could ever be fit for use afterwards, or, at any rate, that the time when it might become fit for use as potable water was very remote; but that, on the other hand, it was only necessary to sink wells deep enough in order to obtain water absolutely free from injurious organic contamination, so that water could be furnished in any degree of abundance by means of artesian wells. On the other hand, there were authorities, not less well recognised as possessing special knowledge and experience, who had maintained that it was quite erroneous to suppose that river water, when it became polluted by sewage, was thereby rendered permanently unfit for potable purposes; that a river had only to flow a comparatively short distance for its self-purification to take place, a purification which, although it might vary in degree according to circumstances, must ultimately he carried out to a sufficiently perfect extent to render the water absolutely wholesome. Probably the truth lay between the extremes; in fact, it was already recognised that it did so, and there were indications that amongst the most extreme exponents of either view there was a tendency to an assimilation of opinions. These subjects had been lately so warmly fought out on many battle-fields that the weak points on each side had become more and more apparent to advocates and adversaries alike; and, therefore, there was a hope that something like that unity of view might, before long, be arrived at, without which any real progress cold hardly be looked for. There was probably no subject which could be selected for discussion which involved so many considerations of primary importance as that of water supply. On the one hand, there were geological, medical, chemical, and engineering considerations; and, on the other hand, there were financial, legal, municipal, and it might be even political considerations. As the Society met on this occasion, in conference in connection with the Health Exhibition, he thought they were primarily concerned with the first-named set of considerations, and their hands would be quite full enough if they limited themselves to these, avoiding, as much as possible, any discussion on the extremely debatable ground of financial or legal questions. They would now at once enter upon the consideration of the first branch of the subject, viz., the Sources of Supply.

I.—SOURCES OF SUPPLY.

ON THE AREA OF CHALK AS A SOURCE OF WATER SUPPLY.

By W. Whitaker, B.A., F.G.S.

Of the Geological Survey of England.

It is only of late years that we have had the means of measuring the area of the great water-bearing formation of the south-east of England that can be reckoned on as a gathering-ground with certainty; and now we can do this for only a limited part of the chalk tract. As it will be a long time before we can do it for the whole, even so far as the London basin is concerned, I have not hesitated to bring forward the subject in its present imperfect state.

On ordinary geological maps, including the greater number of those as yet issued by the Geological Survey, the chalk, beyond the parts where it is covered by the eocene tertiary beds, is shown as bare, except for outlying patches of those tertiary beds (mostly on the high grounds), and for strips of alluvium (or marshland) along the bottoms of the chief valleys. For some years past, however, the Geological Survey has carefully mapped those varying deposits of clay, loam, and gravel, and sand, usually grouped under the name of drift, which cover, in a more or less irregular way, the various divisions of the tertiary beds and the chalk, and which have a marked effect on the nature of the country where they occur to any great extent.

It follows that it is only in those parts of the chalk tract where the Geological Survey has mapped the different divisions of the drift, that we are able to tell, with an approach to accuracy, over how much of the surface the rain has a more or less free access to the chalk, and can therefore sink into it, and add to the supply to be got from it at lower levels.

In the course of a somewhat prolonged and detailed examination of this question, I have constructed a set of maps for the purpose of showing over what areas the chalk is bare, over what areas it is covered by beds of a permeable character (allowing of the sinking of water through them to the chalk), and over what areas it is cut off from the reception of water through being covered by impermeable beds. This may seem, on first thoughts, a simple matter; but, on trial, it is hardly found so, and instead of confining myself to three colours, one for each of the three areas above noticed, I was obliged to use a fourth, for various beds of a doubtful character, either from their being of a mixed composition, or of a changeable one, at this place permeable, at that the reverse.

With these four colours I was at first content; but the fact that in some areas where the chalk is protected by impermeable beds, the water flows over the surface until it reaches the chalk, and then sinks into that rock, has led me to show those areas by a lighter tint, as they contribute somewhat to the water in the chalk, and should, therefore, be distinguished from tracts that do not.

Beyond these five divisions the maps now exhibited do not go; but it may, perhaps, be needful to make a sixth, and to mark off from the rest of the bare chalk those parts where the base of the formation, the chalk marl, is so clayey as to be out of the question of water supply. This tract, however, would be a very narrow band along the outer edge of the chalk.

Possibly too, in extending the work (as I hope to), it may be well to mark areas where beds below the chalk may contribute to its water supply, or where rather the water system of the chalk may join that of some underlying bed. This, of course, would take place where any mass of permeable upper greensand is not divided by clayey chalk marl from the chalk above, in which case there will be but one water system. There is one remarkable part of the chalk tract surrounding the London tertiary basin, where, from the absence not only of the clayey chalk marl and the underlying (but much more local) upper greensand, but also from the thinning out of the usually persistent gault, a markedly impervious bed of clay, it results that the hard ferruginous sand (or carstone) of the lower greensand at once underlies the hard massive chalk. In the north-western corner of Norfolk, where this takes place, from Hunstanton southwards to near Sandringham, the water systems of the chalk and of the upper part of the lower greensand join ; though the lower part of the latter formation is divided off by clayey beds. The supply at Hunstanton Waterworks, close to the base of the chalk, may, therefore, be derived from this composite source, whereas the supply for the Sandringham estate is from the chalk, the clayey chalk marl coming in at that part, and causing an outflow from the more permeable beds above.

The maps which form the text on which this paper is founded, though based on the later geological maps (with drift), follow the latter absolutely in only one particular, that is in the area coloured as bare chalk. As, however, the object in constructing the maps in question was contrast and conspicuousness, their colours are quite different from those of the geological maps ; and, whereas, on the latter the chalk is shown by a very pale green tint, on the former it is emphasised by light carmin. It is only fair to the maps to say that they were not made as diagrams, to be seen at a distance ; but to be examined more closely, and that they have been coloured at various times, as occasion enabled me to take them up. When the work has been further extended, and a large set of maps can be coloured at once by a better colourist, a more harmonious effect may result.

We may now consider the evolution of these "Chalk Area Maps" from the Geological Survey Drift Maps. It will be at once seen that the geological maps are the far more complicated of the two, having a great number of colours and tints as against the five of the other set. My geological friends may, therefore, be inclined to regard the evolution as a case of degeneration ; but, perhaps, engineers may not object to the comparative simplicity of my maps, and to their disregard of theoretical considerations and of geological classification. It should be clearly understood that these maps are meant to show one thing only, that is the accessibility of the chalk to surface-water : they do not always show of necessity the nature of the surface ; but their colours are, in some parts, quite independent of what occurs at the surface, which may be neutralised, for our purpose, by something else that occurs beneath.

1.—BARE CHALK.

As in this case the maps follow the geological ones, there is no need to say more than that bare chalk is taken to include those parts where there is merely a thin soil over the chalk, for that soil is practically unimportant as regards water being pervious.

2.—CHALK COVERED ONLY BY BEDS OF A PERMEABLE KIND.

This includes tracts marked by many colours on various geological maps, permeability being by no means connected with geological age. In colouring these tracts, it was essential to consider not merely the beds shown as at the surface on the geological maps, but to make certain that nothing came between any bed of a permeable character and the chalk, as it is clear, for instance, that ten feet of clay in or beneath 100 feet of sand would stop the downward passage of water through the sand.

The geological beds that fall into this class are as follows: but it should be understood that this is only where one of them rests directly on the chalk, without any bed of an impermeable or mixed kind coming between, or where two or more of them succeed each other without any intervening bed of another kind:—

Thanet Beds, where these are of sand, as in Surrey and West Kent.

Oldhaven and Blackheath Beds, in the few places where they have cut through the under-lying Woolwich and Reading beds, and rest on the Thanet sand or as outliers on the chalk.

Red Crag and Norwich Crag, where they rest on the chalk. Parts of the tracts coloured with the latter on the geological maps are not included, however, on account of the occurrence therein of the clayey Chillesford beds, which must stop the downward passage of water.

Sands and Gravels of the Glacial Drift.

Sands and Gravels of the River Drifts.

3.—CHALK PROTECTED BY BEDS OF MIXED OR VARYING CHARACTER.

In this case it is not essential either that the chalk should be directly covered by beds of the kind indicated, or that such beds should be at the surface; it is only needed that they should occur somewhere between the surface and the chalk, and that no absolutely impermeable beds should come in; permeable beds are of course made of no account by the presence of these mixed beds. Many colours of the geological map find themselves massed in this set, as may be seen from the following list:—

Thanet Beds, where to a great extent clayey, as in East Kent.

Woolwich and Reading Beds, from their varying character, here clay, there sand. There are places, however, where it may be well to include this series with the impermeable beds. The overlying Oldhaven and Blackheath beds, in themselves permeable, are almost wholly carried with this underlying series, except where, as above noted, they have cut through the latter.

Loams of the Glacial Drift. Some of the brick-earth of this age is so clayey, however, that it has been classed as impermeable.

Loams of the River Drifts.

Brick-earth and Clay-with-flints of the high chalk tract. These are beds which commonly occur over the chalk hills, and which, though of a more or less clayey nature, seem not to be wholly impermeable, for they do not give rise to drainage-streams; moreover, they seem, in part at least, to be the result of the dissolution of the chalk by the infiltration of acidulated water. Some outlying patches of sand in East Kent have been classed with these deposits, as they often have a clayey base.

Alluvium.—The silt and peat of our marshes might be thought to be impermeable; but though this may often be the case, these deposits are sometimes sandy, and sometimes very thin, the permeable gravel beneath coming up near the surface.

4.—CHALK PROTECTED BY IMPERMEABLE BEDS.

Here, again, as with the last division, the beds in question need neither rest at once on the chalk nor form the surface; their occurrence anywhere between the surface and the chalk is decisive, and relegates the tract where they occur to what, from our point of view, may be called the useless division, save for those parts of it where the surface waters flow towards the chalk. The large tract marked by the grey colour on the maps, owes its classification almost wholly to the two great clay deposits, the London clay and the boulder clay; but some other beds contribute slightly, as shown by the following lists.

Woolwich and Reading Beds.—In North Suffolk, and in Norfolk, where these beds are quite masked by drift and crag, never cropping out to the surface, they seem to consist chiefly of clay, as proved by well-sections, and it is best to class them with impermeable beds. This may have to be done in parts of the Hampshire basin also, when the re-survey of that tract for drift enables us to construct chalk-area maps of it.

London Clay.—As it is not only where this thick mass of clay forms the surface that it stops the downward passage of water, but also wherever it underlies other beds, it follows that all the overlying permeable deposits have now to be classed with it. This includes the whole of the Bagshot series, so largely composed of sand, which forms such large areas in both the London and Hampshire basins, and also the whole of the very local Coralline crag, which occurs only over a few square miles of Suffolk. Great part of the red crag and of the various drift sands and gravels are also included. All such tracts of permeable beds over London clay, are, of course, of some importance as regards water supply, on a comparatively small scale, and over part of Norfolk and Suffolk no other source of supply from wells is used.

I need hardly say that, in the case of the London clay, my maps add nothing to our knowledge, the position and extent of that deposit being well known, except in East Norfolk and the adjoining part of Suffolk: the above remarks have been made merely to explain the grouping of other beds with it. There are places where the loamy beds at the base of this clay may be sandy enough to allow of the downward passage of water, but such areas must be insignificant.

Brick-earth of the Glacial Drift.—In some parts this deposit is not only of fair thickness, but also of an essentially clayey nature, so that it has then to be classed as impermeable. It often, too, extends underneath deposits of a more permeable kind, and so cuts off their water from the chalk; the underground extension is, however, sometimes hard to trace.

Boulder Clay.—This not only covers the chalk, or permeable beds overlying the chalk, over large areas, but also extends under some of the drift gravels and sands, so that it has a great effect in protecting the chalk from the access of water. A good example of this is given by one of the maps exhibited (sheet 50, S.W.), in which, on an ordinary geological map (without drift) nearly the whole of the 205 square miles represented, would be coloured as chalk—a most delusive thing, as, in fact, the area of bare chalk therein is very small, and the areas of chalk covered by permeable or mixed beds not large, whilst the protecting cover of impermeable beds spreads over by far the greater part.

The map to the north (50, N.W.) is much the same, though we have here rather more bare chalk; but in this sheet the whole area would be coloured as chalk, on an ordinary geological map, except for the alluvium of the streams.

A larger map, not yet coloured after the plan described (on account of the drift edition not being published) is also a case in point, for, in sheet 47, whilst about half the area (of 820 square miles) is shown on an ordinary map as chalk, the impermeable boulder clay occurs over the greater part thereof, and quite alters the character of the district.

Though for the most part a fairly stiff clay, there is one tract where the boulder clay is so largely composed of chalk, almost to the exclusion of anything else, that one can there hardly take it as absolutely impermeable. I allude to the north-western part of Norfolk, where the thin boulder clay of the higher ground is so like the merely weathered surface of the chalk that the officers of the Geological Survey often had some difficulty in dividing the two, especially in places without clear sections. In other parts of North Norfolk, too (near Wells), the glacial brick-earth seems to be represented by a bed which is little else than reconstructed chalk, the specimen having yielded, on analysis, no less than 91 per cent. of calcic carbonate, the other constituents being, moreover, of a sandy rather than of a clayey character, and the whole having some likeness in composition to parts of the chalk.

From what has been said, it is clear, I think, that the "maps of chalk areas" exhibited are not merely another version, or condensation, of the Geological Survey maps, although depending so largely on the possession of these. They show, indeed, some things not shown on the geological maps, and for which approximate lines had to be drawn, and their grouping of the facts mapped is different from that of the geological maps.

It may be of interest, perhaps, to contrast the areas of chalk, &c., as shown by some of my maps, with those represented on geological maps without drift.

Thus, in sheet 7, whilst in the latter map nearly half the area, or roughly about 400 square miles, is coloured as chalk, half (or a little more) being of tertiary beds, and a small area (in the north-western corner) of beds below the chalk, a measurement of the four different kinds of area, described in this paper, gives the following approximate figures, which seem, however, to err a trifle on the side of excess :—

Bare chalk	about	125	square miles.
Chalk covered by permeable beds . . .	„	88	„
Chalk protected by mixed beds	„	180	„
Chalk protected by impermeable beds (almost wholly London clay, there being but little boulder clay over the chalk here)	„	430	„

Again, in sheet 46, S.E., almost all coloured as chalk on the ordinary plan, we get the following figures, as before erring slightly in excess :—

Bare chalk	about	76	square miles.
Chalk covered by permeable beds . . .	„	39	„
Chalk protected by mixed beds	„	67	„
Chalk protected by permeable beds. . .	„	27	„

In 51, S.E., where neither tertiary beds above nor older cretaceous beds below occur, but chalk alone, the figures are about 40, 8, 1, and 155 respectively, various beds of drift (especially boulder clay) generally covering the chalk.

Whilst the general result of the work is to curtail the somewhat excessive estimates that may have been made in bygone years of the amount of chalk area available for the absorption of rain, yet the chalk remains our chief water-bearing bed in the south-east of England ; for, though not always coming up to some of the sand-beds in permeability or porosity, it is pre-eminent over all other geological formations in thickness and extent of outcrop.

Although beyond the immediate object of this paper, there is one circumstance connected with the question of water supply from the chalk which I can hardly help alluding to from its great importance. The present state of the law, as regards deep-seated sources of supply, is the reverse of encouraging to those who advocate the use of pure well water ; for, by a recent legal decision, in the case of Ballard *v.* Tomlinson, it has been declared to be lawful for any one to pour any filth or noxious matter down his own disused well without any regard to the fact that he may thereby pollute the source from which his neighbours draw their supply ! It would be a work of no great difficulty therefore to utterly spoil most well-waters, and this might not only be done by inadvertence, as in the case alluded to, but apparently of malice aforethought. If this is really the law of the land, or rather of the water, there seems to be an opening for law reformers. It is to be hoped, however, that the decision may be reversed in a higher Court than that from which it came. I need hardly say that these remarks apply to all water-bearing beds and not to the chalk only, and, to conclude, I may say the same of the line of observation that this paper brings forward.

WATER SUPPLY IN ITS INFLUENCE ON THE DISTRIBUTION OF THE POPULATION.

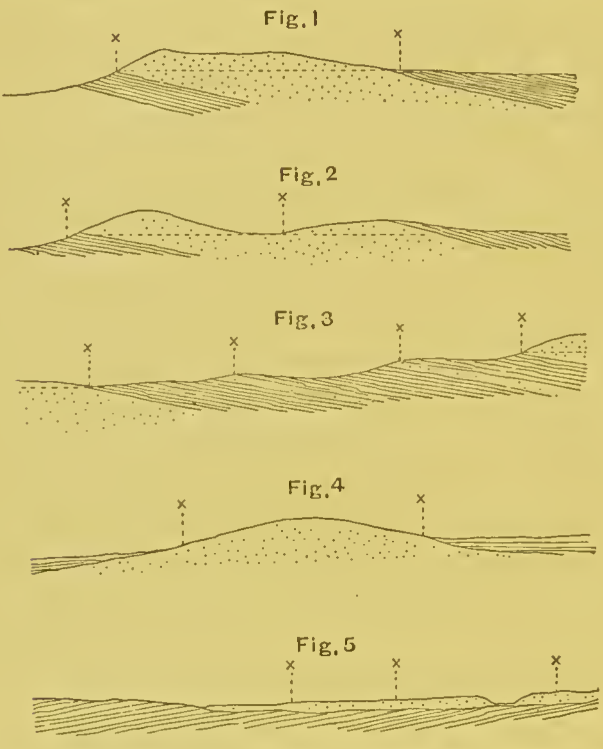
By W. Topley, F.G.S., Assoc. Inst. C.E.

Geological Survey of England. Lecturer on Geology at the Institute of Agriculture, South Kensington.

One of the most essential conditions for the comfort and well-being of a population is water, and a little consideration will show that the early settlements of a people have been where, and only where, water occurs.

In a broad and general sense, this fact is patent to all—the banks of rivers and streams are usually well populated—the wide areas of waterless districts are unpeopled ; but the fact is equally true in a very limited and restricted sense, not at first so obvious.

Sections illustrating the Origin of Springs.



× × Indicate the mere common sites of early settlements ; dots indicate porous beds ; lines indicate impervious beds.

The source of all water is the rain which falls on the land ; this acts in two different ways, according to the nature of the soil on which it falls. If the soil is porous, or pervious to water, a certain portion of the rain sinks in ; if the soil is impervious, the whole of the water either drains off the land into brooks, or passes back by evaporation into the air. The water which soaks into a porous soil or rock, accumulates there until it flows out again as springs, or is artificially tapped, and drawn away by means of wells.

The conditions under which springs most commonly occur may be illustrated by the following "sections," which represent the rocks cut through from the surface downwards. The positions of springs are marked × × ×, and in all cases these also mark the positions in which villages and towns occur.

Springs occur near where a pervious bed overlies or underlies an impervious bed (Fig. 1), or where a valley reaches down to the level at which the rock is saturated with water (Fig. 2). In the case of valleys cutting deeply into the rock, the valleys themselves determine the level of saturation.

A soil which allows water to sink into it is a dry soil, and is therefore suited for habitation and for agriculture. Hence the main conditions which favour the settlement of a district are found in the same soil, or along the outcrop of the same bed. We thus see that geological structure controls the distribution of the population ; not only in such great features of the earth's surface as mountain-chains, plains, and valleys, but also in the minor divisions of the district.

The outcrop of a narrow band of porous rocks, between wide beds of clay, is strongly marked by the occurrence of a long line of villages, each of which obtains its water from shallow wells or springs. The cornbrash, between the Oxford clay and the great oolite clays, is an excellent example of this. So, too, is the marlstone rock-bed, between the upper and lower lias. Even a thin and comparatively unimportant bed of sand, ironstone, or limestone, if it only affords a small space fit for arable culture, will be marked by a line of villages (Fig. 3). A thin bed of ironstone in the lower lias of Lincolnshire is a good example of this.

When rocks rise from beneath a covering of clay there are often springs at the junction. Fig. 4 shows a very common arrangement in East Northumberland, where sandstone rises from beneath the boulder clay.

The base of the chalk escarpment, with the line of outcrop of the adjacent upper greensand, gives another good example. Here the villages always lie thickly along a definite line. There is a well-marked and constant relation between the outcrop of porous strata and the parish or township boundaries, the longer axes of the parishes crossing the outcrops more or less at right angles. A careful study of the distribution of the villages, and of the relation of their parish boundaries to the main physical features, throws much light upon the past history of the country, and often enables us to determine the relative ages of the settlements. This branch of the subject does not now concern us :* we need only note that the arrangement of the parish boundaries depends upon the sites of the settlements, and that these are controlled by the outcrops of water-bearing beds.

The early settlements in England were nearly always controlled by such circumstances as have been here referred to ; but the later development of special towns and districts has depended upon a variety of circumstances. In early times it was around some shrine of special fame or sanctity, or under the shadow of the castle of some powerful noble, that the population clustered and the town increased. A little later it was also in places especially well suited for various manufactures. Within the last 200 years the great development of our mineral wealth (especially of coal and iron) has entirely transformed the country. Large towns have sprung up over the coal-fields, often on wide tracts of clay, where few settlements would otherwise have taken place. The natural surface water supply of such places is often bad and small, and the mining operations frequently drain even this.

The water supply of modern towns is, in nearly all cases, either (*a*) obtained from a neighbouring river, (*b*) brought from a distance, or (*c*) obtained from deep wells beneath the town. It thus, except in the first case, differs from that of the original settlement, which always obtained its water from streams, springs, or shallow wells. In far too many cases the primitive source of supply has been continued in use long after the time when it should have been abandoned; and the local source of water supply, essential to the early development of a town, has become a source of danger as the population has increased.

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* For discussion on this question, see a paper by the author, in "Journal of the Anthropological Institute," vol. iii. pp. 32–55 (with maps), 1873.

Of the points just mentioned, London affords an excellent example. The old parts of London and its suburbs are built upon gravel resting on London clay (Fig. 5). Where small valleys (such as the Fleet) cut through the gravel, there are natural springs; but everywhere water can be obtained in shallow wells sunk through the gravel. So long as the inhabitants were dependent entirely upon these springs and wells, the houses were confined to the gravel; when a general system of water supply was introduced, the population extended over the intervening area of clay. Meanwhile, the increasing population, without any adequate system of drainage, fouled the shallow wells, and rendered them all more or less impure. It is only within the last few years that some of these have been closed by authority.

Below the superficial deposit of gravel, there are other sources of water supply for London. The strata beneath lie in a basin-shaped form, and thus favour the accumulation of water. Underneath the London clay there are the lower tertiary sands, holding water which rises in the wells when these are sunk through the clay. Still lower, there is the great mass of chalk in which there is an enormous store of water. Still lower, and separated from the chalk by a bed of clay (gault), is the lower greensand. This, on the south side of London, may yet yield some water, but it can never be the great source of supply which was once hoped for.

There are, then, with the river, four different sources of water supply at or beneath London, each giving a different quality of water. Probably no large city in Europe is better situated than London for supplying itself with water from within its own area; but so vast has London now become, that all these taken together are insufficient, or inefficient.

It is a curious circumstance that some others of the great capitals of Europe are built on "basins" like that of London, and hence are able to obtain deep well-water from beneath. Paris, Berlin, and Vienna, are good examples. This is a circumstance that could not have been known to the early settlers, who concerned themselves only with the surface sources of water supply.

ON A POSSIBLE INCREASE OF UNDERGROUND WATER SUPPLY.

By CHAS. E. DE RANCE, A.I.C.E., F.G.S., F.R.G.S.

Secretary of the British Association Underground Water Committee.

FOR nearly a century the subject of water supply has been constantly before the public, and with the growth of population has become a question of vital importance to the community. The amount of information that has been accumulated is very large, but, investigated by Royal Commissions, inquired into by committees appointed by scientific societies, it is spread over a wide range of literature. It is difficult for any one individual to focus the stores of information already available, still more for him to follow up the numerous lines of investigation these inquiries suggest.

In my work on 'The Water Supply of England and Wales,' published in 1882, I made an attempt to show what was the probable supply of water available in all the river basins of England and Wales, and what amount was required to satisfy the demands upon that supply, with the result that it appears to be amply demonstrated that the rainfall this country receives is more than sufficient to meet all the requirements of human consumption, manufacturing interests, and the purpose of canalisation; and yet, with these resources, large districts still suffer from all the ills due to a polluted water supply, whilst other large areas are devastated by floods, representing unproductive rainfall passing to the sea.

It is to this unproductive rainfall that I would chiefly wish to call attention in the present communication. Much has been written on underground water supply since the year 1841, when the Rev. James Clutterbuck stated "the extent of the supply must necessarily be regulated by the quantity of rain falling upon the surface, the rapidity with which it is absorbed, and the reduction to which it is subject by evaporation ;" but this definition still expresses the knowledge we have on the subject. Rainfall being the sole source of supply to the waters beneath the surface as well as those flowing upon it, accurate information on the amount of rain falling on a district is a matter of the first importance, and this, to be of any value, must represent the observations of an extended period of years, so that not only may the minimum supply to be expected be ascertained, but the average or mean of several successive dry years also. Happily, through the voluntary labour of Mr. Symons, F.R.S., we have now more than 2500 stations at which rainfall is recorded, and we are able, by consulting his annual volumes, to obtain the necessary information for a large number of localities; but it is obvious that, considering the direct bearing such observations have on engineering, agricultural, and sanitary questions, the scope of the inquiry should be enlarged by placing it under a Government department, which could enlarge the scope and usefulness of the inquiry without being, as now, partially crippled for want of sufficient funds to carry out the necessary details.

Pervious or permeable formations, by gradually absorbing waters falling on their surface, which slowly percolate through them, act at once as filter-beds and reservoirs, the capacity of which is limited by the area of absorption, and the thickness of the pervious bed. When rain falls upon a perfectly pervious rock, underlaid by impermeable deposits the water line is generally near the surface ; this line or plane of complete saturation, in sandstone and limestone hills intersected by valleys, is found to be slightly above the level on which the deepest valley intersects the various strata, constituting the water-bearing rock.

When bands of permeable and impermeable rocks alternate, each porous band contains a separate sheet of water, which flows down the dip planes of the strata, confined by the impermeable layers above and below. Such water flows with the head, due to the difference of vertical level, of the area of outcrop to that of the area of discharge, less the frictional resistance of the fragments of the rock through which it passes. When the facilities for the discharge of a volume are less than the quantity capable of being received, the porous rock will be full up to the impermeable layer above, which is invariably the case when all outlet is stopped by faults throwing in impermeable strata, or by the dip carrying the strata beneath the sea-level.

Such porous rocks may be regarded, when provided with an outlet, as underground conduits, the depth of which is the thickness of the bed, the width of which is the extent of the outcrop or horizontal strike of the bed, and the inclination of which is the dip of the strata. Where the outlet is blocked, the saturation-level remains unchanged, and unless water is artificially removed, so as to provide space for a fresh supply, no additional water can be added to the existing supply.

In sinking wells, or in boring into a mass of porous rock, the plane of saturation is found to vary within certain limits, being governed by the amount of previous rainfall. This level, by excessive pumping, is artificially and locally lowered, but the old " rest-level " is restored after a certain number of hours' cessation from pumping. The difference between the " rest-level " and the pumping-level is, in some wells, in porous strata as much 100 feet. The area of exhaustion resembles an inverted cone, the apex of which rests on the point at which the pumps abstract the water, and the base of which is a circle at the surface around the well. If over-pumping has taken place, the pumps have to be lowered ; the cone increases in vertical height, and a larger concentric circle is added to the central one.

In porous rocks of great thickness the plane of saturation is often at a considerable distance from the surface, the annual rainfall absorbed being balanced by the springs run off at low level, and the floods passing across the outcrop too quickly to sink into the strata. In these cases it would be possible to raise the height of the *saturation-level*, and thus increase the storage powers of the rocks by sinking "dumb-wells" in the porous strata, and draining the storm-water channels into them, which would have the effect of increasing the summer discharge of the springs.

From an investigation I made in 1878, as to the area of each of the various rocks in each river basin, which forms the basis of the paper I laid before the Society's Water Congress, convened by his Royal Highness the President, I estimate the area in England and Wales, occupied by porous rocks, to be not less than 26,633 square miles ; while the tertiary, gault, weald, oolitic, liassic clays, the triassic and permian marls, and the shales of the carboniferous occupy a further 19,308 miles, in nearly the whole of which occur pervious rocks, a larger portion of which might be rendered available for storage purposes by sinking dumb-wells through the overlying strata, and discharging the land drains into them, which would prevent the water passing away in devastating floods.

Experiments were made simultaneously on the percolation of rainfall by Dr. Dalton, at Manchester, and by M. Maurice, at Geneva. Dalton's gauge consisted of a cylinder, 10 inches in diameter, and 3 feet deep, open at the top, closed at the bottom, and filled with earth, and sunk to the ground level ; his experiments were carried on from 1796 to 1798, 25 per cent. of the rainfall being absorbed. M. Maurice's observations, from 1796 to 1797, gave 39 per cent. of percolation. Mr. Dickenson's, from 1836 to 1843, gave 42 per cent. Mr. Greaves' observations, extending from 1852 to 1873, with an average rainfall of 25·8 inches, gave the percolation of 26·6 per cent., his gauge being a slate box with an area of one square yard, a yard in depth filled with soft earth, loam and gravel mixed, trodden in, and turfed over. Mr. Greaves states, "the gauge stands at Lea Bridge, 1½ miles west of, and 6 miles north from the meridian of Greenwich." He finds the abundance of water in a river to be more closely dependent on percolation than on mere rainfall; for consecutive months there is no percolation whatever; five times there was no percolation for six months; and only in one year (1860) was there percolation every month. The greatest percolation is after thaws of snow, especially after frequent thaws of small falls of snow. A wet winter gives abundant springs in the following autumn; but if that be followed by a dry winter, it will obliterate the effect of the previous wet winter; this is the case in the present season, 1884, when the springs are remarkably low, as has been pointed out in the *Times* of June 7, by Mr. Baldwin Latham.

Mr. Greaves's experiments show the smallness of percolation through earth on the whole, and its entire absence during warm summer weather; and they also show the small thickness of earth under which water may be safe from evaporation, which he places at a depth of 36 inches; and even at 24 inches he considers it doubtful "whether, in the latitude and temperature of London, capillarity has more than a negative action beyond 12 inches in depth." Probably, in a moderately open soil, capillarity extends only a few inches, but the higher capillary power of clay soil causes a constant summer exhalation. From these facts it is evident that the more thoroughly a soil is underdrained, the nearer it resembles the "percolation gauge," and the less likely is water to pass off as flood in an open watercourse. The more free drainage is promoted, and the more "dumb wells," or "inlet drains," are constructed, the greater will be the quantity of water stored; in other words, the percolation period, ending naturally in February or March, will be artificially extended so as to catch a large proportion of the summer rains; and "intermittent springs," which are dependent not on surface-present rain, will be increased in volume, and to some extent rendered more permanent, at times when the heavy rains of summer, through excessive evaporation, are adding nothing by percolation to the underground stores.

The investigation of individual observers, and the ten Reports of the Underground Water Committee of the British Association, which I have drawn up, as Secretary of the Committee, have made well known the large quantities of water now pumped from the millstone grit, the permian sandstone and triassic sandstones, the oolites, the greensands, and the chalk ; towns like Liverpool, Birmingham, Birkenhead, and Nottingham, receiving from the triassic sandstones quantities reaching, in the case of the city of Liverpool, 6½ million gallons per day ; while the analyses of the Royal Rivers Pollution Commission, show us the pure quality and great value of these waters from a sanitary point of view.

In England and Wales, the pervious portions of the carboniferous, the secondary, and tertiary rocks, occupy an area of not less than 26,600 square miles, while an additional area of 19,000 square miles exists of rocks of this age, which, though impermeable and carrying off the rainfall in floods, yet overlie pervious strata that might, to a great extent, be made available for storage purposes, were dumb-wells carried into them from the surface ; such dumb-wells would artificially act as do the swallow holes which feed the chalk and carboniferous limestone waters.

In the chalk, though water is absorbed with great rapidity, and retains a quantity, according to the experiments of Professors Ansted and Miller, equal to one-third of its bulk, it parts with it with excessive slowness ; and the water available to feed springs, and to supply well-borings, is mainly due to free water passing down the cracks and fissures which traverse the chalk surface in all directions, the larger fissures allowing the passage of rain water down to the lower portions of the chalk. That the deep-seated impermeable beds occurring at the base of the chalk formed the surface on which the passage of water chiefly took place, was pointed out by Professor Prestwich, in 1851; and the gradient on which water stands in the chalk was described in the Sittingbourne district by Mr. W. Bland, in 1852, which gave an inclination of 47 feet per mile of fall in one direction, and 45 feet per mile in the other; in Hertfordshire, the average inclination between Dunstable and Watford was found by the Rev. J. Clutterbuck, in observations extending from 1842 to 1850, to be only 14 feet per mile. The later observations of Mr. Baldwin Latham on this subject show the remarkable increase of gradient, produced by the temporary rise in the water level of the hilly districts of the chalk, after heavy and continued rains, which becomes gradually depressed after their cessation, before the springs in the low ground have ceased to give their maximum yield.

Over the whole of the area of 26,600 square miles, drawing wells may be sunk with advantage, and their supply increased by sinking inlet or drainage wells to carry into the strata water now almost entirely lost, and rendered not only unproductive of good, but the agent of actual harm, in the destruction of property and agricultural produce by floods. Care will have to be taken that, in constructing such dumb-wells, communication is not set up between drains carrying objectionable matter and the underground sheet of water, and that in draining wells and bore-holes the point at which the water is abstracted is sufficiently removed from the surface to insure the water having naturally filtered through the superincumbent strata.

In the case of the 19,000 square miles of impermeable strata overlying pervious strata, for the most part already containing water absorbed, in the area of outcrop of the pervious, Artesian borings will give large supplies, in numerous districts where no attempt in this direction has been made; and where the Artesian gradient, or water level, is not as high as the base of the impermeable stratas overlying the permeable bed, dumb-wells may also be sunk with advantage, and in relieving the clay beds of their floods in winter, will help to increase the summer discharge of the rivers, and render the intermittent springs of more permanent value.

WATER FROM THE CHALK.

By JOSEPH LUCAS.

AT the first Congress on National Water Supply, convened by the Society of Arts in 1878, I had the honour to read a paper indicating an opinion "that the real stumbling block to the practical solution of the water question of the country in general is not, as has been alleged, its cost, but the general absence of data respecting its sources," and advocating a survey of the water-bearing strata on principles described in the paper, and which I now reiterate.

The proposition met with the support of water engineers, and was endorsed in a leading article in the *Times*, summing up the results of the Congress.

At the next meeting in 1879, at which the Council of the Society of Arts did me the honour to confer upon me their silver medal for a paper on "National Water Supply," in a second paper, entitled "Watershed Lines," I gave the measurements in square miles of the apparent and real areas of chalk country lying within the basins of thirteen rivers between and inclusive of the Medway and the Meon, in South Hants, as determined by my hydrogeological surveys.

In the following year, the Institution of Civil Engineers, who had previously published a map and paper giving the results of a somewhat crude survey of the chalk water system (1872–6), did me the honour to publish a map and paper descriptive of the "Lower Greensand Water System of Surrey and Hants." For this survey the Council of that institution awarded a Telford medal and premium. In its application to the subject of London water supply, the hydrogeology of the question has frequently been called into requisition by the water companies, and was mentioned on the Committee of the House of Commons on London Water Supply, over which Sir William Vernon Harcourt presided, in 1880, by Professor Thorold Rogers, and in the evidence of the late Mr. E. J. Smith. That Committee never got beyond the financial view, and the question of London water supply was practically hung up to await the creation of a Municipal Corporation.

As it appeared to me unfortunate that the survey of the source of water supply should be hung up with it, I have continued to the present time (with the exception of a few months in which I was laid up from ill health) to extend, over large areas, the series of field observations which I have now carried on for nearly twelve years. These materials are in frequent use as evidence before Parliamentary Committees, in the Law Courts, and in arbitration cases at the Surveyors' Institution. As regards special areas, my friend Mr. Baldwin Latham has for years taken a large series of gaugings of wells and streams daily, which are probably unique in this country; and my former colleague, Mr. De Rance, has long edited a collection of observations under the auspices of the British Association, which will be of great value.

This is not the time to go into details of any particular areas, but I may be allowed to present one or two facts from a large mass of unpublished material, in support of any contention that a comprehensive and uniform survey of the sources of water supply is the stimulant required for the flagging water question.

The chalk of the county of Hertford is covered by a varying thickness of drift clay and clay with flints, and the wonderful plains of gravel that occupy nearly all the upland surfaces. From surveys made in 1876–7 and 1884, I have traced out two distinct water systems—one, the deeper, that of the chalk, which at the present time lies far below most of the valley-lines in the chalk basin of the Lea, and another, that of the surface gravels. Many of the various tributaries now in water are surface streams only, and here and there plunge into the chalk beneath. There should be no difficulty in supplying any village in the county, yet such considerable villages as Reed, Kelshall, and Sandon, have no well, and are dependent on ponds, which before the storm of July 9th were reduced to the last extreme of filth.

Essenden is also without a supply, and is under notice from the Rural Sanitary Authority ; but I am told by a member of the Board that they have no knowledge how to supply themselves. As compared with some other chalk counties, there are no very deep wells in Hertfordshire. Along the base or boundary of the tertiary clays it occasionally happens that the drainage of considerable clay surfaces is discharged into the chalk, either by large swallows, as at Farnham, South Mimms, and Chislehurst, or by invisible leakage. Such points afford grand opportunities for collecting water, a fact that has not been lost upon the Kent Water Company at Crayford and Chislehurst, and might be turned to useful account elsewhere.

The chalk of the South Downs presents one or two notable points. Taking the geological unit of some 45 square miles area, between the Arun and the Adur, which it was my privilege to survey in the winter of 1878–9, and the summer and autumn of 1883, the water system shows three basins : one draining west, towards the Arun ; another east, towards the Adur and coast ; and a third, the Finden basin, between the two. The extreme height of the boundary water ridges of the Finden basin, under the escarpment at Sullington Down on the west, and Chanctonbury on the east, is 300 feet : the distance from the rivers, west and east, which run in at mean tide level, being respectively 4½ miles and 3 miles ; and distance from the sea 6 miles. On a cross section of the intermediate or Finden basin, from Sullington Down to Chanctonbury, we find a fall under the valley of upwards of 200 feet in the water line, the water not attaining 100 feet above O.D. at 6 miles inland along the valley. In the Michelgrove basin it falls short of 20 feet above O.D. at 5½ miles inland, under the valley, while 1½ miles to the west it attains 257 feet. A third case is at Lychpole, where, at 3 miles from the coast and the Adur, the water falls to 6 feet above O.D. I have met with no other area which exhibits such clearly defined channels underground as the block of chalk between the Arun and the Adur.

The upper greensand, generally a slender source of supply, presents a notable exception. In June, 1882, I was invited to make a survey in search of a supply for the town of Warminster, and in the course of a few days was surprised to find some abundant springs issuing above Sheerwater Lake.

(1.) Sheerwater Spring Pond, discharging 132 cubic feet per minute (or twelve times the requirements of the town) at an altitude of 476 feet O.D., and 68 feet above the highest point in Warminster. (2.) Glasswell Spring, discharging 7 cubic feet at an altitude of 482·79 feet O.D., or 74·74 above Warminster. (3.) A spring rising in boggy ground at Aucombe, discharging 55 cubic feet per minute. This spring I did not recommend, as it is muddy and peat-stained. The total discharge of Sheerwater Lake was 200 cubic feet per minute, or vastly in excess of all the above which flow into it. The elevated situation of these fine springs places them out of the reach of contamination, an advantage enjoyed by few towns in England. In the case of Warminster it is the more remarkable, as that town stands on the watershed ridge between the two channels. The Local Board is now taking steps to acquire water from them for the town. It is important to note that the mill-owners of the Alyn, last year, failed to establish their claim to compensation in water for the quantity proposed to be abstracted from that flowing down the Silurian mountains on to the mountain limestone in which it sank, before a Committee of the House of Commons. Gaugings were specially taken last July, a temporary dam being formed above the inflow, and suddenly removed to let down a rush of water, which was found to issue a quarter of a mile below, after which it again sank and re-issued. This decision affects several English rivers and streams. Hydrogeological evidence is of the utmost importance in all such cases.

I must call attention to the recent decision by Justice Pearson in the case of "Ballard *v.* Tomlinson" (I being a witness as to facts below ground on behalf of the defendant), that the owner of a well is at liberty to pour sewage, or arsenic, down it if he likes, and to suggest that there is need for a change in the law upon this point, which will become more important if London should ever (and the attention of Sir Francis Bolton should be called to this point) draw more largely than at present from the chalk, as would appear possible after the recent demonstrations of Colonel Beaumont's rock-boring machine in the Channel and Mersey tunnels, and the Halkyn drain in the mountain limestone.

In conclusion, I trust that the present Conference will not break up without passing a resolution to the effect "that a national survey of the sources of water supply, both surface and subterranean, to produce maps defining levels, areas, and quantities of water, should be set on foot by Her Majesty's Government with the least possible delay." I trust that the spirited perseverance of the Society of Arts will be rewarded by a practical outcome from their several Conferences.

DISCUSSION.

Mr. HENRY ROBINSON said he feared, without some further explanation, that the allusion made by Mr. Lucas to the decision of the Parliamentary Committee, not to give the millowners on the river Alyn compensation for water abstracted, might be misunderstood. He was engineer of the Bill before the Committee, and the facts were these. There was a petition from the millowners, asking that the company should give what was regarded as the usual clause, providing that a certain amount of water from the gathering ground should be sent to the stream, but the Committee were of opinion that it was not sufficiently proved that a large volume of the water which went into the river Alyn was connected immediately with the gathering grounds from which the company were to take their supply. There was a doubt whether a large portion of it did not disappear in a swallow, even at the present time ; and as regarded the future, the Halkyn level, which had been referred to, having been authorised by Parliament, was in course of construction, for the purpose of draining a large area of mining grounds ; and therefore it was put before the Committee that a large body of water which was part of the river now, would cease to be so. The case, therefore, was exceptional, and could not be relied upon as a precedent for other cases.

Mr. CONDER said he noticed in the four papers which had been read an echo of what was stated in 1878. A number of individual projects were then brought forward, and, to a certain extent, much harmony appeared to prevail on that occasion. Before those projects were entered upon, he ventured to submit to the meeting that, being so far in accord, it would be well to put their accord on record, and to pass a resolution which might be taken as the unanimous opinion of the Conference. With some lIttle modification that plan was adopted, and the result was an application on the part of the Conference, in 1878, to His Royal Highness the Prince of Wales, to suggest to the Prime Minister the appointment of a small Scientific Commission for ascertaining those facts, which they were now told still required to be made known. The application was made, but through various circumstances was put aside, and nothing had been yet said which did not tend to show the weighty nature of the application. And he would venture to submit whether it would not be a worthy outcome of the present proceedings to repeat the recommendation of the former Conference, and endeavour to obtain further distinct and definite information as to the subject of water supply. The contrast that existed between the information, or rather want of information, on this subject, in this country and on the Continent, was anything but creditable to us. They owed something to the Ordnance Survey, and they owed much to several gentlemen who had devoted themselves to this subject. It was impossible to touch the subject at all without acknowledging what they owed to Mr. Symons for the information he had collected with regard to the rainfall. That information had been collected, in the first instance, by his unassisted efforts, and afterwards by the efforts of an unpaid and disinterested body of fellow workers, which were an honour to the country, but possibly not so much an honour to the Government that such a duty should be left on the shoulders of private individuals. The Blue-books which had been issued by the different Commissions contained a mass of information, and so did the proceedings of the Institution of Civil Engineers. But when they turned to other countries, a very different state of things was to be found. The Italian Government published, in a form accessible at a small cost to every landowner, information as to the flow, both in summer and winter, and all the other particulars of every river in Italy. But if we turned to our own books and proceedings, there was an absolute absence of this fluviometric information which in Italy was at the command of everybody. He need not point out how important it was to the engineer and landowner, or to any one who had to keep off floods, or seek for water, to possess all this information ; and therefore it was not merely as an academical demand, but as a matter of practice, that this knowledge was required. Many of them were aware of the present condition of the Thames, and he apprehended, from instructions recently given by the Board of Trade, that they would shortly be in possession of the actual summer flow of the Thames during July. The lowest account of the flow was that of Mr. Harrison, who put it at 309 million gallons per day. Mr. Bateman put it at 350 million gallons as the summer flow, for days and days together. But the question was whether, with a long series of dry years which might naturally be expected to follow the long series of wet years we had had, a constant supply of 350 million gallons could be anticipated. On the other hand the demand was constantly increasing. The quantity pumped in July, last year, by the five metropolitan water companies, exceeded 75 million gallons per day; and considering that in the Valley of the Thames, not including that of the Medway, there were now something like seven millions of inhabitants, who require 225 million gallons a day, that was making an unpleasant approach to the 350 millions of possible flow. In forty or fifty years, those seven millions would have increased to something like 14 millions, and the 225 million gallons required now would be from 400 to 500 millions. It was tolerably clear, therefore, that it was desirable to know all that was to be known about the sources and the behaviour of the Thames. With regard to dummy wells, it was a local question how far any individual well might absorb a flood, but as to the general idea, he thought all would agree it was a feasible and good one. There was one point to which he would call the attention of practical men which had not yet been touched upon. The Valley of the Thames and Medway included an area of something like 6000 square miles, or 5000 for the Valley of the Thames alone, and of this, according to the figures, something like 4000 miles was a permeable area, of which 2000 were chalk and 2000 miles sand and gravel—a true water-bearing area. The great object of the Geological Survey was to avoid wasting flood-water. The natural storage of this water was the pervious water-bearing beds, and the importance of the information suggested as to the percolation from the surface was no doubt very great. They had the facts of the rainfall, and of course they could get nothing more than the rainfall. About fifteen inches evaporated in the course of the year, which would leave only eleven inches to be dealt with in the Thames Valley, of which it was supposed two or three ran down the river Thames. But in whatever mode the water got into the water-bearing strata, there was no doubt it escaped from it very irregularly. It escaped at the lowest lip of the basin, and if a thorough knowledge of the basin were obtained, it occurred to him it would be possible to raise the lip, and place a regulating sluice there, and by that means, to store one, two, or three years' of rainfall in these water-bearing strata, to be drawn upon as required, and so keep up the flow of the Thames.

Mr. BALDWIN LATHAM said, with reference to the escape of water from the outcrop of the chalk formation, it was quite clear that all round the escarpment of the North Downs a very small quantity flowed away in the opposite direction to the dip of the strata, which was towards London ; in fact, immediately under the chalk there was the upper greensand, which all along the escarpments was worked, at various quarries, both for building and fire-stone ; and the level of the water in those quarries varied with the level of the water in the overlying chalk formation ; and although there appeared to be the chalk marl intervening between the upper greensand and the chalk, he did not think it was of such an impervious nature as to prevent direct communication between the waters of the two strata. In fact, it was clearly shown where the chalk marl came to the surface all along the foot of the escarpments of the North Downs, there were no ditches or streams all along the formation, and all the rain equally disappeared there as it did over the chalk itself ; therefore, practically for all water supply purposes, the chalk, with the chalk marl and upper greensand, might be taken as one stratum. There were immense fluctuations in the quantity which was stored from year to year in these formations. In March, 1883, they had one of the largest quantities of water stored in the chalk of the North Downs and South Downs which had been known for many years, and yet at the end of 1883 they had one of the lowest water periods. That was a thing which had hardly ever occurred before—going from extreme high water to extreme low water in a single year. The maximum probably exceeded the minimum by ten times, and, therefore, when considering the water supply of a particular district, the minimum must be borne in mind, and either the average or the total capacity, seeing there were these immense fluctuations in the quantity of water which were common to all geological formations. The same thing occurred in the new red sandstone, the permian beds, and the oolite, in all of which he had carried on observations for some years. It was absolutely certain, therefore, as Mr. Lucas had pointed out, that a future water supply for underground sources must depend upon correct hydrogeological surveys. When the quantity of water was known, and they could show the yield over certain years, and what area of strata was required to supply a definite quantity of water, there would be nothing to do but to make careful observations in order to get a sufficient supply of water. The question of compensation would naturally crop up, and to his mind there was not the slightest doubt that a single drop of water could not be taken from any of these porous strata without interfering with the flow in some adjoining stream. It seemed, therefore, to be a matter of great injustice that power should be given to water companies to sink wells and abstract water to the injury of those who had property, and often very valuable property, in the water supply, without compensation. The hydrogeological experiments which had been made would tend to show that these areas which were affected contributed their supplies to different rivers, and when it was essential to the public advantage that supplies of water of this character should be procured, it was only right that those who were injured should be properly compensated. With reference to Mr. De Rance's proposition as to the means of storing water in porous strata, of course there were great difficulties in the case of elevated strata, but there were other circumstances in which water might be stored in that way. In the course of his investigations, he had received the most valuable contributions from General Hyde, of the

Indian Railways Department, who stated that in Peshawur, from time immemorial, it had been the practice in the rainy season for the natives to cut channels from the water source to the wells so as to fill up the gravelly strata underneath the more impervious surface stratum, and when the wells were filled in that way they were closed, and only opened in the summer time, so that they had at that period an abundant supply of water which had been cooled by coming in contact with the earth at the time at which it was stored. Therefore, what might appear to be a new idea, was really one of extreme antiquity. The whole question of water supply was one of the greatest importance with regard to the public health, and it behoved them, especially in seeking for these underground supplies of water, to take care that they were sought for at points not liable to contamination. Many underground sources of water supply were polluted to a frightful extent ; and really the cause of his undertaking these investigations was the repeated outbreaks of typhoid fever in the district with which he was especially connected. Having been able to collect statistics for some fifty years back, he could say with confidence that there was the most marked parallelism between the state of the underground water and typhoid fever. Not only so, but these statistics showed very clearly that there appeared to be a ten years' periodicity in low water times. One of the lowest water periods in this country occurred in the cholera year of 1854; another very low water period occurred in 1864, and another in 1874 ; and two years ago he predicted, as the result of investigations, that there would be a low water period this year. There was not a shadow of doubt in his mind that over a large portion of England we should have the water lower this year than it had been for years, and the consequence would be that the diseases which followed those periods were likely to be more rife than they had been for some time past.

Mr. W. SMARTT said he understood that the water at Birkenhead was contaminated in a very serious manner, and knowing that a patent was applied for not long since, for a method of draining land in a particular manner into the chalk, he thought it was hardly advisable to go to any great expense in taking water from the chalk, seeing that there was a danger of its being seriously contaminated. Laws might be passed to prevent the passage of drainage from houses into it, but if the level of the water under London were lowered to any great extent, it was quite possible to cause a flow back from the lower part of the river. For instance, there was said to be a fault in the chalk at Woolwich, and on a former occasion it was stated that the water supply at that place was frequently contaminated from that cause. There were also faults under the Thames, and if the water were lowered, there would be a flow back which might not be noticed for a considerable time, and eventually the whole body of the chalk water might become contaminated. There could be no doubt that the water was absorbed by the chalk beyond the amount absorbed in the first instance, for having placed a piece of chalk in water, and allowed it ample time for absorption, and then placed it in a vessel where it remained for some time, he found that not a particle of water ran out. His opinion was that water should be taken from the springs along the course of the river, whilst it was still pure. The water could be obtained at a depth of 30 or 40 feet all the way up the valley of each river, and it might be taken out of the chalk or other porous strata. It was shown that about half of the chalk district about London was covered with an impervious stratum, though the surface might be pervious, as it was reasonable to suppose it would be, because all the marsh land was flat, showing it was formed from sediment washed down from the hills, and being washed down gradually, it must necessarily be more or less porous, and contain a large quantity of water. With regard to swallow holes, it had been stated at a former meeting that there was a passage in Lincolnshire extending some miles under land, and out to sea.

Mr. JOSEPH QUICK, jun., said, referring to the statement of a previous speaker as to the condition of the Thames being at present so extremely low, that only 350 million gallons a day passed over Teddington Weir, he knew that information to be perfectly accurate. The question he wished to ask was, why advantage was not taken of the enormous quantity of water which flowed at other periods over the weir, and which, so far from being useful, was, on the contrary, a very serious detriment to navigation? If those responsible for the water in the Thames stored up the winter floods, they might thereby regulate the flow throughout the year, and the condition of the river would be much improved, with advantage not only to those who took from it, but to those who lived on the banks. With regard to the case of the river Alyn, he had the misfortune to be opposed to Mr. Robinson before the Parliamentary Committee, but he certainly thought Mr. Lucas went a little too far in saying that the decision of the Committee formed any precedent for future cases, and that millowners were not to be compensated for water of which they were deprived by water companies or others. The circumstances were quite exceptional, but the Committee did not lay down any precedent to prevent millowners in future cases asking for water compensation.

Mr. W. B. KINSEY desired to corroborate Mr. Baldwin Latham's remarks with regard to the question of periods of drought. From his own investigations he found that ten years ago there was a drought, and again ten years before that, and there was the same drought now. He could also concur in what he said about the water flowing against the dip of the upper greensand. He was now carrying out works in the neighbourhood of Petersfield in the upper greensand, where the facts fully bore out what had been stated.

Mr. W. A. RICHARDSON said he had heard it stated with great surprise that the wells at Birkenhead were polluted. The water at Liverpool was taken from boreholes in the red sandstone, 450 to 460 feet in depth, and the water was frequently analysed, and was considered to be the best and purest in the kingdom.

Mr. LUCAS, with reference to the case of the river Alyn, produced a section showing the exact state of the case, and remarked that what he said in the paper was that it would affect similar cases. The section showed that the water flowing down the slanting strata sank into the limestone and ran a quarter of a mile underground in a course that was not known, and it was on that ground that the Committee refused compensation. Of course rivers which had no such underground course, would not be affected.

The CHAIRMAN then proposed a vote of thanks to the four gentlemen who had read the papers, which was carried unanimously, and the Conference adjourned for a short time.

THE ORIGIN OF WATER SUPPLY.

By G. J. SYMONS, F.R.S.

THIS title might possibly be supposed to imply a history of the past, but in this Health Exhibition, *pace* Old London, we deal chiefly with the present and with the future.

I know no better word than origin wherewith to describe the small portion of the great subject of water supply which I am permitted to discuss.

All water supply comes from the clouds, and it is with the products of the clouds as rain (including therein snow and hail) that I have to deal.

Perhaps before describing the general features of rainfall distribution, it may be permissible to explain (for the use of those who have never done it) how the fall of rain is measured. If we imagine a flat dish—a tea-tray, for instance—placed upon a lawn during rain, it is obvious that (subject to loss by splashing) that tray would at the end of the shower be covered by a layer of water of a depth approximately equal to that which fell upon all portions of the lawn, and the depth of the water on it (say ½ inch) would be the depth of the rain fallen. Obviously, besides the loss by splashing, the water on this tray would soon evaporate and be lost, besides which the depth could not easily be accurately measured. For these reasons, some form of funnel is always used, so that the rain may be, as it were, trapped, prevented from splashing out, and from evaporation. In the gauge before you (a very inexpensive one) all known sources of error are guarded against, and, as the water collected by a 5-inch funnel is measured in a jar only 1½ inch in diameter, it will at once be seen that its vertical depth is multiplied nearly tenfold, and, therefore, even $\frac{1}{100}$th of an inch is easily measured.

There are other patterns specially adapted for observation on mountain tops, where they can only be visited once a month; others for observations during heavy thunderstorms, so as to obtain data needful for drainage questions; others in which every shower that falls writes down its history, the instant of its commencement, its intensity during every minute, and the time of its termination; but I must not stand between you and other papers with a discourse on the many interesting points which these gauges bring out.

During the last twenty-five years, I have done what I could towards establishing a complete system of recording the rainfall in this country. In early days the British Association for the Advancement of Science gave considerable help, but some ten years since they dropped it. Government have never given any help at all, and now the whole cost, or 99 per cent. of it, is borne by the observers themselves, a body which has now grown to the very large number of nearly 3000. I do not know the precise number, but there are every year new stations beginning, old ones stopping, and others interrupted; yet for 1883, I have just had the pleasure of printing perfect records from 2433 stations, every record having been previously carefully examined and verified.

Hitherto, I have been so overworked, and my staff has been so small, that the discussion of the data falls behind the collection; for this reason I cannot lay before you such data as I wish. However, the map on the wall is the one I drew many years ago, and which was inserted in the sixth report of the Rivers Pollution Commission. It is not perfect, but as it is tinted with increasing darkness for places with heavy annual falls of rain, it will at least show you the broad features of the distribution over the country.

I refrain from going into the subject in detail, desiring chiefly that you should realise the fact that large tracts of country have twice and even three times as much rain as others. If we descend to single stations, the differences are of course greater, *e.g.*, in 1883, the rainfall at The Stye, in Cumberland, was 190·28 inches, and at Clacton-on-Sea, in Essex, it was only 18·71 inches; that is to say, the one was more than ten times the other.

Here I should like to interpose a question as to public policy. There is often a great outcry if the water of one district is taken to another. Surely, while there is no relation whatever between the density of population and the quantity of rainfall, one early duty of a Government is to see that all parts are amply supplied with the chief necessary of life. Englishmen have a dread of centralisation, but in many ways they pay a long price for their dread. At present, it is not often that any town can even state before Parliament its views as to the effect upon it of what its next neighbour may be obtaining powers to do. Having suggested one semi-legal question, I may as well mention at once another. Up to the present time, there being no Hydraulic-office (as I hold that there should be) in this country, all the larger water questions come before Parliament as private Bills, and, provided that they get through Committee, they, as a matter of course, become law—law for all time to come. No one can foresee what will be the total population of this country a century hence. No one can tell where the bulk of the people will reside, nor what will be the need for water in various parts of the country. Water-rights are already very valuable, and they will probably become still more so. Would it be possible to safeguard our successors by insisting that special water-rights, if now asked to be created, shall be subject to revision, *without compensation*, after the lapse of 100 years?

However, to return to rainfall, and explain why I stated it to be the origin of water supply. All rain and melted snow must be disposed of, either by evaporation, percolation, or flow into streams and rivers. The first class, evaporation, is, of course, not a supply, and therefore we must not pursue it. Percolation is the source of all springs and of all well-water. Sometimes, as at Lancaster, the springs are so large, that even a considerable town can be supplied by merely laying pipes to the sources whence they burst forth; sometimes they run into the reservoirs of gravitation water-works; sometimes they pass, as in the chalk districts, for miles beneath impervious strata, finally being either pumped up from wells, or even, in rare cases, rising as true Artesian wells above the surface of the ground; and sometimes they pass even deeper, as in the red sandstone supplies pumped from extreme depths for Liverpool and other towns.

The water which runs off the surface is sometimes utilised by throwing a bank across a stream, and thereby forming a reservoir behind it, as, for instance, in the new supply for Liverpool from the Vyrnwy, where the reservoir will form a lake larger than many of those in Cumberland. Sometimes the lakes themselves are utilised as reservoirs, as, for instance, Loch Katrine and the surrounding lakes, and sometimes, as at York and London, the rivers are drawn from by powerful pumping machinery.

It is often said there are few things so uncertain as the rain. That is both true and false. True as regards our ignorance of the future, false as regards our knowledge of the limits within which the quantity of rain will be found to vary.

There are now hundreds of records of rainfalls in this country of thirty or more years each, and in a very large majority of them it will be found that the following proportions will be within 7 per cent. of the truth :—

Wettest year, 45 per cent. more than the average.
Driest year, 33 per cent. less than the average.
Driest two consecutive years, 26 per cent. less than the average.
Driest three consecutive years, 21 per cent. less than the average.

There are many other facts respecting the laws of rainfall distribution, concerning which time prevents my saying anything, but I trust that enough has been said to establish the necessity of a perfect system of rainfall registration as the basis of any efficient hydraulic organisation.

DISCUSSION.

Mr. E. K. BURSTAL thought Mr. Symons had made out a very strong case indeed for limiting to some extent the period to which water rates should be absolutely unalterable. They had been accustomed to consider that the three driest consecutive years were one-sixth less than the average, but he now showed that they were one-fifth less ; and as the difference between one-fifth and one-sixth was considerable when dealing with very large quantities, that was a sufficient reason why some such suggestion as his should receive serious consideration.

Mr. LIGGINS wished to point out the great importance of using rain gauges. Some thirty years ago he spent a month in Santa Cruz, and there he found the rain gauge was the first thing which interested the manager of an estate when he got up in the morning. The next year he visited his own estate in the island of Antigua, and found only two rain gauges in a whole group of islands ; but in consequence of what he had seen in the Danish islands, he interested all his friends, from the Governor downwards, in introducing the system. The result was that every estate in the island from that time had constantly used the rain gauge with great satisfaction. The same course had since been adopted in Barbadoes, and he only wished the farmers of England were as enlightened as the planters of those islands, and would see the importance of having rain gauges on every farm in England. He was quite sure they would be pleased with their week's work when they came to tabulate it, and would find the benefit of the information thus obtained. When there were such divergencies as were indicated on the map, there was a clearly proved necessity that, in every district, they should know what they might expect, so as to guide them as to the desirability of commencing the various agricultural operations.

Sir ROBERT RAWLINSON, C.B., remarked that the rain gauge only afforded part of the information, and that a very imperfect part, of that which was necessary for the engineer in pursuing his practice. The rain gauge recorded the rain that fell into it ; it did not record the evaporation that took place outside of it. In this country a season might have a rainfall which should take place in a certain order, and which would register in the rain gauge a certain quantity of water, but scarcely any of that water would have been available for the engineer. For instance, in this country, after a continuance of dry weather, a heavy shower on the mountainous districts in Wales, or elsewhere in the kingdom, would do very little for the engineer, because nine-tenths of the water would go back into the atmosphere before it got down into any stream to feed a reservoir. That was a fact which young engineers should know. If in the mountains of Wales, for instance, a rainfall of 2½ inches took place in a week, and then stopped, there would be no feeding water for an engineer's reservoir. Then, if an interval of dry weather should take place, and another 2½ inches of rainfall during a week (which would be a tolerably heavy fall), the engineer would have no feed into his reservoir. He could mention one instance where, on the east coast of England, a reservoir which he had himself constructed was run dry, and for twenty months continuously there was no rainfall in that district which was capable of feeding it. Those were important facts which young engineers must take into account.

Mr. MACKNIGHT, with regard to Mr. Symons's reference at the end of his paper as to legislation being very desirable on the subject, said that gentleman had not told them in what direction the legislation he desired should proceed. For his own part he considered that a great deal of injury had been done to the country and to the public interests by premature and rash legislation on these subjects. He thought a great deal more information was required on scientific points before such attempts were made. In Scotland, in various sanitary matters, a great deal of harm had been done by premature legislation, where persons holding particular views on matters of scientific observation had influence enough to get legislation passed in those directions, and it had then turned out that instead of doing good it had done a great deal of harm. A great deal more information should be before the public and scientific societies before such attempts were made, and he deplored the fact that the country should be allowed to suffer from premature sanitary legislation.

A vote of thanks for the paper was then passed.

WATER SUPPLY TO VILLAGES AND RURAL DISTRICTS.

By EARDLEY BAILEY-DENTON, C.E., B.A., OXON.

Author of *Handbook on House Sanitation.*

I BELIEVE that I am uttering a fact which no one can discredit, when I state that there is no object in social economy which is more important, having regard to the aggregate number of persons affected by it, than the supply of water to village communities and rural districts.

At the present moment, when the International Health

Exhibition may help to draw attention to sanitary objects of varying degrees of importance, it may be well to make clear that the condition of rural districts, in relation to water—the first essential of healthy life—is a positive disgrace to a country represented by a State Department whose efforts, it appears to me, should be specially directed to the protection of small communities less able to help themselves than large ones ; and is a sad reflection on the present advanced stage of sanitary knowledge—an admission which the special meteorological condition of the present season, and a possibility of a visit of cholera, brings home to all minds with increased force.

If it should be understood, too, that the existence of this condition of things is to be traced, not so much to the absence of potable water, or the difficulty of bringing it into use, as to the disinclination of local authorities to develop the capabilities at their command.

It may be said with truth that, as a general rule, Local Boards and Boards of Guardians having jurisdiction in rural districts, who have been called into existence to supply the sanitary requirements of those districts, are animated with less desire to perform the duties devolving upon them than to avoid them. It is indeed notorious that the majority of members of Local Boards are elected under a pledge to oppose such works as sewage and water supply, on the ground that the rates will be increased ; and knowing this to be the case, and that few persons of superior position are willing to take part in Local Boards, because they would invariably be outvoted, it is easy to understand why rural districts should be the last to move in the water question. It is, however, very difficult to explain why the clergyman and medical man of rural parishes, whose higher education should be a guarantee that the right thing would be done, fail to exercise proper influence. If, perchance, they are elected to serve on Local Boards, it almost invariably follows, that the one forgets what he has said in the pulpit as to the influence on the Future of sudden death ; whilst the other ignores the advice he has given his patients in their sick-chambers, in relation to the fatal effects of inhaling and imbibing those germs of disease which float in foul air and impure water. Directly they are easy in their chairs as members, they content themselves with the *laissez faire* policy of their colleagues.

These influences explain how it is that local authorities abstain from appointing as surveyor or sanitary inspector any man with a capability and courage to expose local defects and requirements, and why, when a medical officer does his duty in explaining the defective character of the water supply of any portion of his district, some reason is soon found for relieving him of his duties, and for appointing another in his stead; the actual result of all this being that the governing bodies of rural and small urban districts exercise their functions, when compelled to act, not by taking the advice and opinion of men technically qualified to guide them, but by the exercise of their own judgment. You may often observe a small publican or a grocer—excellent tradesmen in their respective vocations—directing the sinking of wells in village streets in close proximity to leaky sewers, ditches, or cesspools, by which the water intended for the supply of the poorer inhabitants soon becomes foul and unsuitable for domestic use. So general, indeed, has been this abuse, that it is no exaggeration to state that nineteen out of twenty existing village wells are quite unfit for their purpose, and that if samples were honestly taken and submitted to a competent analyst they would be condemned. Yet they are permitted to exist, and nothing is said about them, because the populations interested are comparatively small, the death rate is not excessive, the dwellings are low in value, and, above all, because the rates would be increased if a proper water supply was substituted.

I have been induced to offer some remarks upon the present occasion, not because I have anything especially new to lay before you, but because the facts I have just referred to, on the constitution of local authorities and the performance of their duties, have been made more pertinent by the circumstance that, at a time when there exists the apprehension of a visit of cholera, a scarcity of water may occur, owing to a remarkably dry winter being followed by an unusually hot summer, which the recent thunderstorms may not sufficiently counteract. It is unnecessary to explain that the summer supply of water is very greatly dependent upon the fall of rain during the preceding winter, *i.e.*, upon the rain falling in the non-evaporating and dormant months of November, December, January, and February. The mean amount of rainfall in those months of the last winter did not reach two-thirds of the average quantity due to the same months for the preceding 60 years. This deficit would have been much more severely felt at the present time, and would have affected our subterranean supplies much more than it is now likely to do, had it not been in some measure counterbalanced by the excesses of rain which occurred during the last seven years, from 1876 to 1883, which gave us, on the whole, a considerable balance to carry over. This advantage, coupled with the frequent and heavy thunderstorms which have occurred within the last month or two, will go far to prevent the scarcity of water which would otherwise have occurred during the coming autumn; though, unfortunately, this national advantage will be a poor compensation to the agricultural interest, which has suffered so severely from the excessive wetness of the last few years.

Without taking into consideration on the present occasion the use of rain water, which, under careful management, may be collected from roofs, and other impervious surfaces, and stored in tanks, and which will always form a valuable means of supply to private dwellings, and in special instances may be made available even for villages, our rural supply, now so often derived from dirty ditches and shallow wells, more or less polluted by foul matters, may, in the absence of springs, rivulets, and impounded upland surface waters, be obtained from subterranean sources of "wholesome" character. These are to be found in various beds or outcrops of a water-retaining character, which gather water at a comparatively shallow depth below the surface, such as the post-tertiary beds of Norfolk and Suffolk, and the different drift beds covering the London clay; the Bagshot sands; the green sand overlying the wealden and gault clays; the surface sands and beds of the wealden formation; the calcareous grit and coral rag outcropping between the Kimmeridge and Oxford clays, and other beds of like nature; or, from the well-defined water-bearing strata of the chalk, the oolite, and the red sandstone formations which are deep lying, and to reach which it is often found necessary to pass through superincumbent impervious beds or strata of varying thickness.

From the first source, it requires comparatively little motive power to raise the supply to the height required; in fact, in many cases, the application of the ordinary lift or atmospheric pump suffices; in others, where the depth exceeds thirty feet, additional power is called for. The second source requires more powerful pumping, and may involve the use of several pumps working in unison. All this has been said and explained before. My desire now, is, if possible, through the influence of this meeting, to impress upon Local Boards and Boards of Guardians in rural districts where, in order to obtain unexceptional potable water they are obliged to seek it from beneath the surface, that the experience already gained in tubular wells goes far to prove that, in the majority of instances, the "tubular" system may, with good effect, take the place of the old and more expensive practice of sinking large wells involving brickwork, steining and staging. Economy, important though it be, is however secondary to the more important fact that a tubular well signifies continuous and watertight piping from the surface of the ground to the subterranean water-level beneath, so that the entrance of polluted surface or subsoil water (as is so frequently the case in ordinary shaft wells) is rendered impossible. In addition to this advantage, it should be pointed out that tubular wells are very rapidly made, and can be readily removed should it occur that the water found or sought has not answered expectations in quantity or quality. Moreover, the whole of the materials employed may be applied, when withdrawn, to the same purpose in another place.

I may here state that there are some few disadvantages attending the adoption of tube wells which it is right at once to refer to. One is that, if owing to accident pumping is stayed, there will be no supply during such time, and if it should happen that the stored supply should run out before the pumping is resumed, much inconvenience may be experienced; whereas in ordinary shaft wells, there being room for more than one pump, such an objection may be obviated. Another disadvantage is that should the demand for water increase beyond the capability of supply the only remedy is to sink others, and to utilise two or more in combination.

To render the nature and cost of tubular wells, which necessarily vary in character and size according to local circumstances, as intelligible as it is possible to make them to rural sanitary authorities, I may shortly state that, adopting for illustration the two characters of the tubular wells already mentioned, *i.e.*, those that can be worked by ordinary lift and atmospheric pumps at a depth of less than 30 feet from the surface, and those that raise water by more powerful machinery from deep subterranean water-levels, the *modus operandi* and cost will be as follows:—

In the first instance, taking, as examples, cases where the populations may severally be 400 and 1,000, and where there exists a constant supply of water at 20 feet below the surface, recourse may be had to Norton's Abyssinian tube wells. The water is reached by driving tubes down through the ground to the water level. The first tube is pointed and perforated for a few inches with holes varying in size from $\frac{1}{8}$ to $\frac{1}{4}$ inch. Length after length of tubing is driven into the earth at the selected site, and each succeeding length is connected with the last by a screw joint. The perforations at the base are four times as much as is necessary to obtain the full flow of water from the tubes, and they are kept clear by an arrangement adopted by

Messrs. Legrand and Sutcliff, of Bunhill-row, City, for forcing out any sediment or matter that may obstruct a free influx of water. This is effected by suddenly liberating a column of water after it has been raised to a sufficient height above its normal level. The number of tube wells required in a village of 400 would probably be two, and in one of 1000 people, probably five. From figures kindly given to me by the patentees, it would appear that the capital expended in providing the wells and appliances will not exceed 2*s*. per head of the population. Of course, this only refers to the provision of the tubes, the pumps, and the cost of fixing them. There are many instances of small villages and hamlets where one well and pump alone would suffice; but there are others besides those given as illustrations where a number of these wells may be necessary, and which should be united by means of a cast-iron horizontal main or mains, with intervals between the vertical pipes, governed by the nature of the water-bearing seam out of which the water supply is obtained. This distance may vary from 18 to 30 feet. The motive power to work the pumps may vary in kind; water-power may be used when it is close at hand, or gas where it can be readily obtained.

In the second instance (deep sources), the tube wells consist of iron piping fixed in bore-holes, which latter, in fact, form the well, with the piping to serve as the pump barrel and rising main, to raise the water into a service reservoir. These bore-holes will vary in depth according to local features, and in diameter from 5 to 15 inches, according to the quantities of water to be raised. The core of pipes form, as already intimated, a continuous tube from the surface of the bore-hole to the water level below, and are made perfectly flush both inside and out, and must be watertight. They are sunk for a sufficient depth below the standing water-level as to secure an effective discharge. The pump is fixed within the tubing, which forms a cylinder, and it is connected with the engine on the surface by rods properly guided within the tube. Special pains are taken so to construct and fix the pump, that it may be readily brought to the surface, repaired, and replaced. For the first 15 or 20 feet of the well, a shaft 5 or 6 feet in diameter is necessary, in which to fix the necessary gearing connecting the engine with the pump, and to place the air vessel, &c., regulating the lifted supply to the reservoir. It would appear from figures, supplied me by Messrs. Tilley, of Walbrook, for works which we have now in hand, that the primary outlay varies from £500 in a case where the lift is 100 feet, the supply 40 gallons per minute, the depth of the bore-hole 300 feet and its size 7 inches, to £750 where the lift is upwards of 250 feet, the supply 50 gallons per minute, the depth of the bore-hole over 300 feet, and its size 9 inches.

Besides tubular wells sunk perpendicularly into subterranean water, supplies may not infrequently be obtained by the use of syphons for drawing water out of water-yielding basins, to which there is no natural outlet, by deflected pipes laid over or through the rims of the basins. The extraction of the required supply is effected by dipping the shorter leg of the syphon into the water bed forming a ready-made reservoir, and carrying the larger leg into the village requiring the supply, to act, with proper appliances, as a service main. This automatic mode of raising and delivering water has already been found available for towns as well as villages.

In the cases of Abingdon and Warwick, a syphon arrangement has been found very beneficial. The firm to which I belong, when devising the water supply for the former town (under the immediate supervision of Mr. C. F. Gower), adopted this expedient for raising the necessary supply for a population of over 6000, which we had intended to obtain from a direct adit driven into the bed of coral rag, or calcareous grit, outcropping between Boars Hill and Abingdon, but which we abandoned in favour of a suggestion from Mr. J. Thornhill Harrison, of the Local Government Board, who, at an inquiry held by him, pointed out that the water bed which we were making preparations to tap might be considered a natural reservoir, from which the required supply could be raised by means of a syphon passing over the bank impounding the water. This object was effected by means of a 9-inch pipe capable of discharging 330 gallons a minute, laid from a reservoir holding 125,000 gallons (which it was found necessary to make within the calcareous grit for storage and ready discharge), the bottom of which was 40 feet higher than the highest part of Abingdon. The shorter leg of the syphon is about 9 feet in length, and reaches very nearly to the bottom of the reservoir. When the water, finding its way out of the calcareous grit into the reservoir, rises above the crown of the syphon (which it generally does during the night), the discharge is by gravitation independently of the syphon ; but when it sinks below that level, then the syphon action is called into play. This arrangement has been in existence at Abingdon for four years, without any hitch or difficulty of any kind.

At Warwick, Mr. Edward Pritchard, C.E., adopted a somewhat similar contrivance, whereby he effected a very great saving in the cost of the works. It has now been in operation for more than eight years, and is stated by Mr. Pritchard to work satisfactorily. Syphons, whilst working automatically, involve very little outlay in maintenance, and they would be adopted much more frequently than they are at present, if their special nature and advantages were more fully understood. They have been used with great advantage for the drainage of land and for the lowering of water standing in bogs. I may mention, as an illustration, that in Scotland the Earl of Stair drained by this means a wet marsh near Culhorn House, which had rendered that residence unhealthy. The syphon-pipe (seven inches in diameter) was half a mile long, and it has drawn down the water nine feet.

There is yet another means of obtaining water for villages, which it would be wrong to exclude from the consideration of sanitary authorities, as in some instances, we know from experience already gained, that it can be resorted to with advantage; I refer to the use of waters from cultivated surfaces, which the Rivers Pollution Commissioners have designated "suspicious" waters. To raise them above suspicion they should be collected and filtered through a bed of natural soil, extending to about one pole (of superficial area) per head of population. By this means the water would be made very superior to that consumed by the majority of householders in rural districts. The preparation of filter-beds of natural soil is simple enough. A plot of land, as porous and free in its subsoil as can be obtained, should be selected and made suitable by special treatment, at such an elevation relatively to the land from which the water would be obtained, and to the village which it is intended to serve, as will receive the off-flow from the former on its surface, and allow it, after it has passed through the filter, to collect in a storage reservoir, and thence to reach the village at a serviceable height. The filter itself should be deeply underdrained, and the water to be filtered through it evenly distributed over its surface. No manure whatever should be applied to it.

The water of under-drainage, when found to contain ingredients of an objectionable character, which the analyses of Professor Way have shown may be the case, can be rendered perfectly unobjectionable by a second filtration through a plot of prepared soil, rigidly preserved from the application of manure.

When we are taught by chemists to believe that the extraordinary purifying powers of aërated soil will render innocuous the discharged sewage of towns in which exists organic nitrogen in considerable amount, we must be satisfied that, by a second passage through natural soil, the water of under-drainage, already once filtered, may be freed from any putrescible ingredients it may have once contained.

This expedient is only suggested where a village being in the neighbourhood of an estate which the owner has underdrained, such owner will allow the water to be diverted from a natural stream, and filtered before it is supplied for domestic use.

I will close this short paper by drawing the attention of sanitary authorities in rural districts to the "Reservoirs Act, 1877," by which powers are given to the owners of land to supply water "to any sanitary or other local authority" by contract, and to charge their estates with the outlay on works.

WATER SUPPLY.

By EDWARD EASTON, M.Inst.C.E.

THE object of this paper is to put before the Conference, in as concise a form as possible, the considerations which should govern the supply of water for domestic and other purposes, not with the intention of enunciating any new thing, but with the hope of drawing attention to well-recognised principles, which are too often forgotten or neglected.

The three chief points which have to be considered in relation to this subject are :—

1. The source of the water.
2. Its distribution.
3. The conditions under which it is used.

1. With regard to the source, it is evident that, in designing a waterworks, the engineer has to provide that the water shall be adapted to the purposes for which it is intended to be used, both as regards quality and quantity.

The question of quality will depend upon circumstances. It is essential, of course, that in every case the water shall be free from contamination by organic and other impurities ; but the necessity of its being chemically free from other constituents will depend, to some extent, upon the purpose for which it will be used ; for instance, in a manufacturing district, where the water is required for dyeing and such-like purposes, it must be free from certain mineral ingredients, whereas for the supply of drinking water and for general purposes, this is a qualification which need not be insisted on.

It is now generally admitted that a soft water is preferable to a hard water, provided that the storage and distribution are properly carried out, and in every case where there is a choice of supplies, that which is soft, or which can be softened by simple means, should be chosen.

The process invented by Professor Clark for softening hard water by the deposition of a portion of the lime, is of a very simple character, and it has been successfully adopted in many cases.

Sources of water proper for use may be classed under two distinct heads. 1st. Those which are afforded by nature in a state absolutely pure and fit for use, such as water drawn from wells and deep-seated springs. 2nd. Those derived from water-courses or gathering grounds which are open to the atmosphere, and which must necessarily be exposed to the risk of contamination from external agencies.

In the case of the former, no works for storage or purification are necessary, the stratum of rock or other material from which the water springs, forming a natural reservoir and filter.

In the second case, it is necessary (*a*) that all direct pollutions shall be prevented from coming into the source ; and (*b*) that in almost every instance, efficient means of filtration should be provided. The filtration ought wherever it is found impossible to altogether prevent the chance of contamination, to include the use of some deodorising agent, of which there exist more than one capable of practical application.

As instances may be mentioned the filtration at Wakefield, where, for many years, by the use of Spencer's magnetic carbide of iron, a water very much contaminated was rendered perfectly wholesome ; and that at Antwerp, where Professor Bischof's spongy iron is employed with an equally good result.

2. Essential as it is to ensure that the source of supply is proper for the required purposes, it is equally essential that the mode of distribution shall be such as shall prevent its deterioration before being used.

To effect this, it is absolutely necessary that the reservoirs, into which the water is collected for distribution, should be covered, and that the mains and pipes should be perfectly air-tight, and laid at a proper depth below the surface, so as to preserve the water in its original state of purity, and, as much as possible, at the same temperature, during its passage from the source to the consumer.

One great cause of the complaints of the quality of the water in most large towns, is the use of cisterns for storing it in the houses, which it is impossible to employ without the risk of some injurious effect upon the water.

In the Session 1877–8, two Bills were introduced into Parliament, at the instance of the Metropolitan Board of Works, for purchasing the undertakings of the London water companies, and for providing a separate supply of drinking water from the chalk. During the exhaustive examination of the waters supplied by the companies, made by the eminent gentleman who so fitly and ably occupies the chair, Sir Frederick Abel, assisted by Dr. Dupré, Mr. G. H. Ogston, Professor Voelcker, and the late able chemist of the Metropolitan Board, Mr. Keates, it was found that, whilst the water delivered in the mains was in almost every case excellent, the position and condition of the cisterns too frequently rendered it utterly unfit for human consumption. A great number of cistern deposits from all quarters of London were examined by these five gentlemen, with the general result just stated.

It is scarcely credible that the favourite place for fixing the cistern from which the water for drinking and culinary purposes is drawn is immediately over the water-closet or next to the dust-hole, whilst even in the better class of houses, where the cisterns are fixed in the roofs, they are very rarely sufficiently covered, and are open to contamination from soot, dust, inroads of black beetles, and other abominations. The latest researches of scientific men show that there is no more fruitful source of disease than such a condition of things affords. Although, doubtless, a great deal has been done by the expansion of the system of constant service in London and elsewhere to remedy this frightful evil, the following extract from Sir F. Bolton's report for the month of May shows that there is still much room for improvement. He says:—

"In the monthly and annual reports on the metropolitan water supply, attention is drawn to the necessity which exists for a regular cleansing of cisterns, and also to the fact that contamination of water from gases generated by sewage is of far more frequent occurrence than is generally understood. Waste pipes from cisterns are still to be found which are in direct communication with drains, so that gases may flow back into the cistern and become absorbed by the water. To prevent this an overflow pipe should be brought outside each house and the end left exposed to the air, instead of being carried into a drain, as is often the case. By the adoption of this plan poisonous effluvia and gases from drains would be got rid of, which would otherwise ascend through the pipe, and not only be partly absorbed by water in cisterns, but be mixed with the air in the houses, thereby becoming a cause of disease.

"The attention of consumers has been drawn to the fact that, in houses supplied on the constant system, all danger of drinking stale or contaminated water from cisterns may readily be avoided if the following recommendation is carried into practice, viz., to attach a small draw-off tap to the communication pipe which supplies the cistern from the main in the street, from which water may be drawn at any moment, day or night, direct from the works, thereby taking full advantage of any efforts made by the companies to purify the water to the utmost extent. This water should be used for drinking and cooking, and the contents of cisterns made use of for washing, flushing, baths, and similar purposes."

An abstract from these reports of the water examiner is printed by the companies at the back of the collectors' rate papers, so that no consumer of water can now be exonerated from the charge of negligence if this abuse is allowed to continue in his house.

3. This consideration naturally leads up to the third division of the subject, viz., the conditions under which water should be used. And first it is essential that a constant supply should be given, without which it is difficult to avoid the deterioration of the water above alluded to.

Not only is it impossible to give an adequate supply by the intermittent system without having storage cisterns in the houses, but there is also a serious danger of contamination by the possible admission of foul air or gas into the mains when the water is turned off. There have been several instances of a water supply being seriously affected from this cause.

But to give constant service it is absolutely necessary also that the supply should be under proper regulations, which shall ensure the prevention of undue consumption and misuse of the water.

Not only are the difficulties of providing the supply greatly increased where waste is allowed to prevail, but the cost to the community is augmented without the slightest corresponding benefit to health.

Nothing is more fallacious than the idea, prevalent among a large section of consumers of water, that the allowing of taps and water-closets to run to waste assists in the flushing and cleansing of the sewers, and therefore conduces to health. These continuous dribblings of water can have no effect whatever in removing any obstructions or accumulations which may exist in the large drains. The only proper and effectual way of removing fœcal matter is so to regulate the use of water that it shall be proportionate to the work it has to do at the moment. Where this is done, by the use of properly constructed water-closets, well-proportioned drains, and by keeping out from the system of sewers the rainfall on the streets and houses, the ordinary quantity supplied to a town is quite sufficient to perform this service without having recourse to extraordinary means. The question of dealing with the sewage of large communities, which is now so full of difficulty, would be much more easy of solution if these principles were more generally acted upon.

For these reasons, it is not desirable that the supply should be unlimited in quantity; on the contrary, every precaution should be taken to make that quantity commensurate with the real wants of the consumers.

It is quite certain that in almost every town a very large proportion of the water delivered through the mains runs needlessly to waste.

To take an example on the largest scale, the quantity supplied to London, according to Colonel Sir F. Bolton's return for the month of May, amounts to 32 gallons per head per day, about 20 per cent. of which, or say 6 gallons, it is estimated is used for other than domestic purposes, leaving 26 gallons per head as the quantity supposed to be absolutely consumed in the houses. Now it has been ascertained that, on the average, the water really required is not half this quantity; and there is also no doubt that, by taking proper precautions, the amount delivered can be made to approximate very nearly to the actual use.

At Liverpool, by means of careful inspection of fittings, aided by the use of Deacon's meter, a most ingenious arrangement, by which it is easy to localise, and therefore detect, waste, the consumption of water has been reduced from 33 to 22 gallons per head per day, and, within my own experience, the adoption of the same system has, in six or seven instances, produced even more satisfactory results.

The waste of water, whether it arises from leaky joints in the mains and service pipes, or from defective fittings inside the houses, can only be injurious to health from the increased humidity which is thereby imparted to the soil and atmosphere, and which, as is well known, contributes so much to the spread of infectious diseases and the establishment of epidemics.

At this moment, when we are suffering to a greater extent than usual from the contamination of the Thames, owing partly to the presence of a large quantity of sewage, but also to the abstraction of so large a proportion of the summer flow of the river, it is manifest that the reduction by 33 per cent. of the amount drawn from and discharged into the river would go far to ameliorate the condition of things now complained of.

Among the different proposals which have been made for the introduction of a system which would ensure the prevention of waste, is that of furnishing the supply by meter. This is open to the grave objection that, in order to save money, people would be tempted to go to the other extreme, and to content themselves with an insufficient quantity. To obviate this, some such arrangement as that proposed by the writer to the Select Committee of the House of Commons, over which Mr. Ayrton presided in 1867, might be effectual. The following extract from the evidence given before that Committee will explain the proposal :—

"I think a better method altogether might be devised of supplying the houses in London with water—a better system might be adopted to prevent waste. I should provide a constant service by meter, but under different conditions to any hitherto proposed. I think it could be designed with perfect fairness to the water companies and to the consumers, by making certain arrangements, and the general principle upon which I would propose that that should be done would be this: that there should be a sliding scale adapted to the class of house, and that each house should have a certain amount of water allotted to it. I would take a £100 house, and allot to it 150 gallons per day, and to a £200 house I would allot 300 gallons of water per day, and so on, upwards and downwards, provided that no house should have less than 50 gallons. Let the companies charge the same rate as they do now for that minimum quantity of water, and if more is consumed or passes through the meter the consumer would have to pay for that additional quantity."

Although at first sight the expense of the meters would appear to be prohibitive, both the consumer and supplier would soon be reconciled to the outlay, the one because he would know what he was paying in proportion to the water he received, and the other because they were only supplying water for which they were paid.

The consideration of the subject of this paper would not be complete without a reference to the important question of the conservancy of our rivers.

It is useless to discuss the method and conditions of supply, if the sources of water are not to be preserved to us, and it is quite certain that, with the immense growth of the population of this kingdom, it will not be long before this preservation becomes a pressing necessity.

In the report presented to Parliament by the Duke of Richmond's Select Committee on Conservancy Boards, in 1877, a very workable scheme was recommended by their Lordships. The Committee say that:—

"In order to secure uniformity and completeness of action, each catchment area should, as a general rule, be placed under a single body of conservators, who should be responsible for maintaining the river, from its source to its outfall, in an efficient state. With regard, however, to tributary streams, the care of these might be entrusted to district committees, acting under the general directions of the conservators; but near the point of junction with the principal stream they should be under the direct management of the conservators of the main channel, who should be a representative body, constituted of residents and owners of property within the whole area of the watershed."

But although the question of improving the water supply by preventing the pollution of the rivers, was incidentally mentioned by their Lordships, it is evident that the main object of the report was the prevention of floods, and not the conservancy of water for the supply of populations. Now, it may well be said that the one subject is at least as important as the other, and just as the recurrence of a number of wet seasons at that time brought the question of the floods prominently before the Duke of Richmond's Committee, it may safely be asserted that a corresponding succession of dry seasons will compel the serious attention of the Government to the other part of the subject. We need go no further than our metropolis for the proof of this, for if, in addition to the saving of water by the prevention of waste, the flow of the Thames were properly regulated by works in the higher parts of its watershed, there is no reason why the river should not be in a condition which although leaving very much to be desired in the way of improvement, would yet be tolerable, and, according to past experience, absolutely not injurious to health.

When presiding over the Mechanical Section of the meeting of the British Association, at Dublin, in 1878, on which occasion the opportunity was taken to very fully discuss, from a variety of aspects, this question of rivers conservancy, I made a suggestion which, I believe, is worth repeating at the present time. In my address to the Section it was stated :—

"When it is considered that many lives are annually sacrificed, either directly by the action of floods, or by the indirect but no less fatal influence of imperfect drainage,—when it is remembered that a heavy flood, such as that of last year, or that of the summer of 1875, entails a monetary loss of several millions sterling in the three kingdoms ; that during every year a quantity of water flows to waste, representing an available motive-power worth certainly not less than some hundreds of thousands of pounds ; that there is a constant annual expenditure of enormous amount for removing *débris* from navigable channels, the accumulation of which could be mainly if not entirely prevented ; that the supply of food to our rapidly growing population, dependent as it is at present upon sources outside the country, would be enormously increased by an adequate protection of the fisheries; that the same supply would be further greatly increased by the extra production of the land, when increased facilities for drainage are afforded; that, above all, the problem of our national water supply, to which public attention has of late been drawn by H.R.H. the Prince of Wales, requires for its solution investigations of the widest possible nature,—I believe it will be allowed that the question, as a whole, of the management of rivers is of sufficient importance to make it worthy of being dealt with by new laws to be framed in its exclusive behalf.

"A new department should be created—one not only endowed with powers analogous to those of the Local Government Board, but charged with the duty of collecting and digesting for use all the facts and knowledge necessary for a due comprehension and satisfactory dealing with every river-basin or watershed area in the United Kingdom—a department which should be presided over, if not by a Cabinet Minister, at all events by a member of the Government who can be appealed to in Parliament."

It is earnestly to be hoped that no further time will be lost in passing an Act to deal with this subject, and that no considerations of a party or private nature will be allowed to prevent a scheme of so important and imperial a character being made as complete and comprehensive as possible.

In conclusion, as I commenced by saying, I have not attempted to say anything new; indeed the subject has already been in the hands of far abler exponents than myself; especially would I refer to Dr. Frankland's very able and comprehensive Sixth Report of the Rivers Pollution Commission, the careful study of which is recommended to everybody who wishes to master the details of the question.

SOURCES OF WATER SUPPLY.

By JAMES MANSERGH, M.Inst.C.E., and M.E., F.G.S., F.M.S.

It used to be a popular belief that if a well were sunk at any place to a sufficient depth into the ground, there would be reached an inexhaustible reservoir of water, a store that had been filled in some mysterious manner at the creation of the world, and would suffice for the use of man for all time.

It is now well known that all supplies of water, whether found upon the surface, or below it, in underground depths, are derived from the rain which falls upon the earth, and that it depends upon the geological character of the surface receiving the rain whether it shall run off in the form of streams and rivers, or soak in and be apparently lost.

Rain is produced from the evaporation of invisible aqueous vapour, principally from the ocean, by means of solar heat, its condensation, primarily into the shape of clouds, and subsequently into the form of drops, which fall to the ground.

The sea is thus a storage reservoir of boundless capacity, and the sun is the great prime mover which pumps the water up from this reservoir, distributes it over the land, and lifts it to the hills, where it may be impounded in natural or artificial lakes, and thence delivered by gravitation to the plains below.

After being discharged on the earth in the shape of rain or snow, a part of the water is re-evaporated, but the greater part begins at once to travel downwards, either over the surface, in the form of rills and streams, and so on to the ocean whence it came, or through the surface, if this is permeable, into fissured or porous rocks below.

A portion of this latter water passing into the ground at high levels, has several courses open to it. It may appear in the shape of springs at lower levels, or rise in the beds of rivers, or run out through fissures on to the sea beach, or sink below sea level, whence it will be recoverable only by artificial means.

Nature has in this way provided water from one great source in ample quantity for the use of man, but works of varying character, under differing local circumstances, must be constructed to store and utilise it.

Altitude and the geological structure of a district are the two principal factors which determine what the source of water supply must be in such district. The two great classes into which sources may be divided are (*a*) above-ground and (*b*) underground sources.

The former (*a*) has several subdivisions, which may be described as follows :—

1. Water may be taken from the heads of streams by laying pipes right up to the springs, to convey it away for supply without any intermediate storage, as in the case of Lancaster. This is a source which in some sense belongs to the two classes, for the water is taken just as it ceases to be underground water, and is being delivered on to the surface above ground.

2. It may be obtained from a natural lake like Loch Katrine, as in the case of Glasgow.

3. It may be collected from a high-lying watershed area, by impounding a number of small streams in artificially constructed reservoirs, as is done for the supply of Manchester.

4. It may be taken from a large river flowing past a town, as is done in the case of the Thames and Lea for the supply of London.

The second class (*b*) is not divisible in the same way as (*a*), but may be taken as embracing supplies of water obtained from many varieties of geological stratification, such as chalk, oolites, coal measures, millstone grit, magnesian limestone, Bagshot sands, and many others.

All water, when discharged upon the earth as snow or rain, is practically pure, but its character is very soon changed by the material it comes in contact with on the surface, or in passing through underground fissures and channels. Take, for example, the rain which falls upon the chalk downs of Sussex or any other similar geological area. It sinks at once beneath the smooth and rounded surface, and percolates through innumerable minute cracks or larger fissures, dissolving away the chalk which it touches, and finally issues naturally in springs along the coast, or is pumped out artificially, a water which contains from fifteen to twenty-five grains per gallon of carbonate of lime.

Such an alteration in character depends of course upon the nature of the rocks which the water traverses, some rocks being easily soluble, others not.

The taking up of lime or magnesia in this way has the effect of rendering the water "hard," that is, increasing its soap-destroying properties. For many manufacturing processes this is a most undesirable quality, and we therefore find that many of the important industries of the country are located in districts where soft water is easily procurable.

The following are the formations which yield as a rule soft water :—Igneous, metamorphic, cambrian, silurian (non-calcareous), Devonian (non-calcareous), millstone grit, coal measures (non-calcareous), lower greensand, London and Oxford clay, Bagshot sands, non-calcareous gravels.

On the other hand the following geological formations almost invariably yield hard water :—Silurian (calcareous), Devonian (calcareous), mountain limestone, coal measures, (calcareous), new red sandstone, conglomerate sandstone, lias, oolites, upper greensand, chalk.

The manufacturing towns of Lancashire and Yorkshire obtain their supplies from sources which, even if the water had passed underground, would leave it comparatively soft, but this quality is fully secured by the character of the works, which consist of large reservoirs impounding the water which has principally run merely over the surface.. For dietetic purposes, the quality of hardnesss if not excessive, that is if it does not exceed twelve grains on

Dr. Clark's scale (equivalent to twelve grains of bi-carbonate of lime per gallon), is not considered objectionable on physiological grounds. For ordinary domestic purposes, and especially for personal washing and cleaning generally, soft water is infinitely preferable to hard, both in respect of comfort, efficiency, and economy.

Taking into account all the purposes for which water is used, it can hardly be questioned that a pure soft water supply is on the whole preferable to a pure hard water supply. The term "pure" is here used to imply the absence from the water of organic impurities as distinguished from the dissolved inorganic matters which have before been referred to. Except as producing hardness, the inorganic matters usually found in water are practically harmless; but organic pollutions may be of the most disgusting and dangerous character, those for instance which are the result of contamination with town sewage or cesspool manure.

It is to avoid the risk of such pollution that many towns have in great measure been led to seek their sources of supply on elevated moorlands, above the level at which arable cultivation is carried on, and where it follows that there are no towns or villages, and the scattered population is very sparse. In this country the plough is rarely seen above the 800 ft. contour, and as it will not pay to cart manure to such an elevation, these high lands are merely used for the pasturage of sheep and the rearing of grouse.

Water obtained from such sources is practically, therefore, in the condition in which it falls from the clouds as snow or rain. The only impurity it may contain is a little organic matter derived from passing over the peaty soil, which often occurs on high moorlands, especially where the summits are broad and comparatively flat. This contact with peat, and with growing heather, gives a stain to the water to such an extent that, when seen in deep reservoirs, it looks like dark coffee.

As seen in an ordinary white glass bottle or tumbler, the tinge is rarely deeper than a very faint straw colour.

There is nothing harmful in this colouring matter, because it is of purely vegetable origin, and to some extent it may be removed by storage in open reservoirs, or running in open channels exposed to the air.

Many towns are so located in this country that it is practically impossible that they should obtain pure water supplies from elevated water-sheds, on account of the enormous expense that would be entailed in the construction of the necessary works. Such places must be content to be supplied from rivers in their immediate neighbourhoods, and which, having run their courses through many miles of highly manured lands and past thickly populated towns and villages, contain water which has necessarily become polluted by the washings from the lands and the sewage from the towns. Such sources as these would be inadmissible, but for the great rehabilitating process which nature silently carries on in a river, and to which chemists apply the term "oxidation." In this wonderful process, the polluting organic matters which the water contains are converted by the agency of oxygen into harmless inorganic salts, and the water again becomes fit for the use of man.

This statement must, however, not be made without some reservation and explanation, because chemists of the very highest standing are not agreed as to the extent to which rehabilitation of the water is carried. This has, in fact, become quite a burning question, and the battle has been fought long and frequently over the water which is taken from the Thames, and delivered for consumption by the inhabitants of London.

The difference of opinion is now narrowed down into a small compass, and to outsiders it would appear that there is a chance, sooner or later, an agreement may be come to between the authorities.

As representatives of the two sides may be named Dr. Frankland and Dr. Meymott Tidy. Dr. Frankland admits that oxidation is effective in burning up, or converting into a harmless condition, even such vile contaminations as human sewage, if this is in a normal or healthy condition; but he contends that the virulent zymotic diseases are propagated by organised germs contained in the sewage which are indestructible, and which may travel scores of miles in a running stream without being deprived of their fatal potency.

Dr. Tidy contends, on the other hand, that there is no evidence of the existence of these animated germs, and affirms that a run of a few miles in a river fully oxygenated, and in which the pure water bears a sufficiently high ratio to the polluting matter, will suffice to render such water again fit for human consumption.

Dr. Frankland's theory is naturally a disquieting one; and his opponents certainly have facts in their favour, for London is undoubtedly one of the healthiest cities in the world, and its inhabitants have never been known to suffer from disease induced in the way suggested.

The "germ" theory is, however, making steady advances under the investigations and researches of competent men, and it is to be hoped and expected that if the historic germ is at last discovered, and exhibited to the incredulous gaze of Dr. Meymott Tidy, he, or some of his *confrères*, may speedily discover a method of scotching it before it has time to do any mischief.

It may now be convenient to describe shortly a few typical examples of the utilisation of the different sources of supply which have been thus generally referred to.

I. Take, first, such a case as that of Lancaster, whose works supply a population of between 30,000 and 40,000. The town is situated on the river Lune, about seven miles above its junction with Morecambe Bay, and is built upon a site which, rising from the river, varies in elevation from 15 to 200 feet above Ordnance datum, or mean tide level. The water is obtained from the high moorlands of Wyresdale, at a distance of eight or ten miles from the town, in a south-easterly direction. These fells, as they are locally called, constitute the extreme north-easterly portion of the watershed of the river Wyre, a small river which also falls into Morecambe Bay near the town of Fleetwood. That portion of the fells which is secured by Act of Parliament as a source of water supply for Lancaster, has an area of 2700 acres, and an altitude varying from 850 to 1800 feet above the sea.

The geological formation of the gathering ground is millstone grit, covered with scant herbage suitable for sheep pasturage, and heather. Interstratified with the beds of permeable grit stone there are layers of impervious shale which, at various levels, throw out the water percolating downwards from the surface, in the shape of springs, and a number of these springs have been intercepted by small pipes communicating with mains laid along the hill-side, and leading their combined waters to the south-west corner of the reserved area.

One of these mains forms part of the original works constructed under the superintendence of Sir Robert Rawlinson, C.E., C.B., in the year 1852; the other, which runs (broadly speaking) parallel to the first, but about 200 feet lower down the hill-side, was laid six years ago, as part of an extension carried out by the writer.

The water derived from these is of necessity of the purest possible character, for the rain which feeds the springs falls upon the clean open moorland, and sinks at once into the millstone grit rock, in which it finds nothing to dissolve and cause hardness, and nothing to organically pollute.

The water issues from the springs in a bright sparkling condition, at a constant temperature of about 45° F.; it contains only one grain in 15,500 of solid matter, and its hardness is under 1° on Clark's scale.

This may be fairly regarded as an ideally perfect source of supply, and it has been an inestimable boon to the inhabitants, especially as it replaced water obtained from shallow wells in the town, polluted in the vilest possible manner by percolation from numberless foul and reeking privy pits and middens.

Between the fells and the service reservoir, which is situated on the town moor 240 feet above Ordnance datum, the country is intersected by several valleys, across which the water is conveyed in iron pipes.

At two intermediate points the pressure is broken by small covered tanks, and the water is never exposed to the open air from the time it sinks into the ground as rain or snow, and is drawn from the consumers' taps in the town.

Perhaps it may be as well to explain here that, when water is obtained from elevated watershed areas of this character, Parliament almost invariably insists upon "compensation" being made to the river for such abstraction. This compensation is secured by the construction of reservoirs somewhere upon the main river or its tributaries, in which water is stored in time of flood, and given out in a constant stream in times of dry weather, the assumption being that floods are utterly useless, if not damaging, to riparian owners and millowners, whilst it is of advantage to every interest to have the dry weather flow increased in volume.

Thus, in the Lancaster case, whilst the Corporation have the right to take 2,000,000 gallons a day from the springs for the use of the town, they were put under the obligation to construct upon the river Wyre a reservoir capable of holding 185,000,000 of gallons, from which the millowners have the right to draw water according to their needs during the summer months. By means of such works, all the parties concerned are very greatly benefited.

II. The second type of utilisation of sources which may be referred to, is that which is exemplified on so magnificent a scale in the works supplying Glasgow, and constructed from the designs and under the superintendence of Mr. John Frederick Bateman, C.E.

In this case, advantage is taken of three natural lakes, viz., Loch Katrine, Loch Venachar, and Loch Drunkie. The watershed area draining into these lakes is 45,800 acres in extent, and consists of unpolluted sparsely populated moorlands, the geological formation being of silurian age.

Loch Katrine has a water surface of 3000 acres, Loch

Venachar 900 acres, and Loch Drunkie 150 acres. They are all of course supplied by the rain which falls upon the 45,800 acres, and as a considerable proportion of this area is of a peaty character, the streams which run down the mountain sides are frequently as dark as London porter. By the deposit of the heavier parts of the peaty matter, and the bleaching action of the air, the water is drawn from Loch Katrine with only a faint tinge of colour.

The two smaller lakes are utilised as compensation reservoirs, the artificial storage necessary being obtained by raising the original normal level of Loch Venachar 5 feet 8 inches with power to draw it down 6 feet, and by raising Loch Drunkie 20 feet, the raising in both cases being done by masonry dams across the outlet valleys, furnished with draw-off sluices.

The storage for the supply of Glasgow is obtained by works which raised the normal level of Loch Katrine 4 feet and admit of drawing down 3 feet. Its capacity is, therefore, 3000 acres of area, by 7 feet in depth, equivalent to nearly 1000 million cubic feet, and competent to furnish 50 million gallons a day during a four months' drought.

The water surface in Loch Katrine is 360 feet above mean tide level at Glasgow. The conduit conveying the water to the city commences on the south side of the lake, about three miles from its western extremity, and runs generally in a southerly or south-westerly direction. At 26 miles from the Loch it discharges into an artificial reservoir of 70 acres in extent, and holding 500 million gallons near Mugdock Castle, the top water of this reservoir being 311 feet above mean tide at Glasgow. Two lines of three feet cast-iron pipes, one seven miles long and the other eight miles, convey the water to the city.

For thirteen miles out of the twenty-six between Loch Katrine and Mugdock, the conduit is formed by tunnelling through very hard rock, such as whinstone, gneiss, and mica slate; the tunnels being seventy in number, nine miles of the remaining length is "cut and cover" work, and the rest consists of cast-iron or wrought-iron pipes across valleys.

The advantage of such a source of supply as Glasgow's is the facility and small cost with which the storage capacity necessary to furnish the requisite daily quantity for consumption and compensation is obtained.

In Loch Katrine, the narrow outlet from the lake had only to be dammed up four feet, requiring artificial works of the simplest character, entailing no risk or contingency in their execution. Having a flat area 3000 acres in extent to begin with, a simple plank one foot high would have sufficed to impound 816,000,000 gallons. The desirability of securing such a reservoir site as this can only be fully appreciated by those who have had the responsibility and anxiety of forming large storage reservoirs, by the construction of high embankments across valleys. The relative amounts of labour and outlay in such reservoirs, and in cases like Loch Katrine, will be better realised in considering the next type.

III. The third type of works for the utilisation of mountain watershed sources of supply is well exemplified in the Longdendale valley, where a number of reservoirs have, during the last thirty years, been constructed for the supply of Manchester. Here, instead of having a level plain 3000 acres in extent, as in Loch Katrine, upon which to commence as the bottom of a reservoir, was a valley with a fall along the bed of its main stream—the Etherow—of between 60 ft. and 70 ft. in a mile. Across this valley five embankments have been constructed of earthwork, one above another, forming five lakes with a combined water surface area of 462 acres. Beginning from the lowest part of the valley, the following is a list of the reservoirs, viz.:—

	Height of Bank. Feet.	Water area. Acres.	Capacity. Gallons.
Bottoms	66	50	407,000,000
Vale House	55	63	343,000,000
Rhodes Wood	75	54	500,000,000
Torside	100	160	1,474,000,000
Woodhead	80	135	1,181,000,000
Total	376	462	3,905,000,000

These embankments, which cost something like £100,000 apiece, have an aggregate height if placed one above another of 376 ft., and the quantity of water they impound is 3905 million gallons. The raising of the water surface of Loch Katrine 5 ft. would create the same amount of storage. The watershed area supplying these reservoirs is 9300 acres, and the geological formation is millstone grit. The gathering ground is a portion of the western slope of the "backbone" of England, otherwise the Pennine range, upon which, over its whole length on both sides, many similar works are located for the supply of the manufacturing towns of Lancashire and Yorkshire. The rocks in this district are very much fissured and broken, and the rain falling upon the higher grounds percolates below the surface and reappears as springs at lower levels. Advantage is taken of this by conducting the spring water along special channels into the Rhodes Wood reservoir, from which the supply is taken by a conduit to the town.

Although the quantity of water yielded by the whole gathering ground is that due solely to its area and the rainfall upon it, the fact of there being these springs renders it more valuable, because it implies that water which would have run off a district composed of harder and less pervious rocks, is here absorbed into the mass, which thus acts as so much storage or reservoir space. The effect of this is to increase the dry weather flow of the streams, and to furnish water which is clear, cool, and colourless. The average annual rainfall upon the 19,300 acres is about 50 in., and the works utilising this area are competent to provide 38,000,000 gallons per day, of which 13,500,000 have to be delivered into the stream below the reservoirs as compensation water. Besides the five reservoirs above named, there are other large impounding and service reservoirs at Godley, Denton, Gorton, and Prestwich. In the construction of these works enormous difficulties have been encountered, and at Woodhead, the highest reservoir of the series, the embankment, as at first made, was not watertight, so that a second trench had to be put down in which to build the puddle wall, and so much were the measures disturbed and distorted, that on the south side of the valley this trench had to be excavated to 167 ft. below the surface of the ground, before sound and tight material was reached upon which the wall could be based.

The three types of works thus described may fairly be said to exhaust the methods of obtaining water from sources situated on elevated mountain gathering grounds. They are good examples of the gravitation system of supply, by which water is delivered at high pressure above the highest parts of the towns without any artificial pumping being required, the sun having done this work in the process of evaporation.

IV. We will now consider a case where the town to be supplied is at such a distance from high ground that the cost of bringing it through conduits or pipes by gravitation is prohibitive.

Take a town built along the banks of a river anywhere above the range of the tide. If this river flows through an agricultural district, and is thus not polluted by manufacturing refuse, and not seriously by either manure or sewage, it may be adopted as the source of supply. In this case the water will have to be lifted by artificial means to such an elevation as is necessary to command the whole town.

The water will also require filtration, because in running its course through the country the river receives the washing from the land; and in times of heavy rain, at all events, the water will be discoloured and turbid through the presence of suspended matters.

The works for the supply of London are in great part of this character, the rivers Thames and Lea being the two sources.

Three hundred years ago, water was obtained from the Thames at London Bridge, and pumped by means of a water-wheel under one of the arches through wooden pipes into the streets and houses in the neighbourhood. These works were continued in operation for 200 years, and were supplemented early in the 17th century by other pumping stations, taking water from the Thames at Charing Cross, Battersea, Vauxhall, and Hammersmith, all within the range of tidal influence.

In 1848, the Lambeth Water Company obtained powers to go into the non-tidal portion of the river above Teddington Lock, and by the year 1851 they were in a position to deliver water by means of a large steam-pumping establishment erected at Seething Wells.

In 1852, an Act was passed which made it unlawful for any company to supply water taken from the river below Teddington Lock, or from any of its tributaries within the tidal range. This led, finally, to all the companies drawing water from the Thames so rearranging their works as to have their intakes above Moulsey Lock, in order to be above the junction of the river Mole, which frequently brings down very dirty water.

Owing to the changes in the points of intake, the works of the London companies are divided into portions at great distances apart. Thus the Southwark and Vauxhall Company have at Battersea the reservoirs, filter beds, and pumping machinery constructed for the purpose of taking in water from the river at that point. They are well known to all Londoners by reason of the tall stand-pipes which form a prominent object in the view from the trains running out of Victoria Station.

These works are of so costly and extensive a character, that they could not be abandoned when the source of supply was changed to Hampton, twenty-one miles higher up the river, but the water abstracted there is pumped down to them through large cast-iron mains, to be filtered and distributed by the original machinery and mains.

In the case of the Lambeth Company, the water is taken from the Thames at Moulsey, and sent down to Surbiton, which is the site of the filtering and pumping station, through a large brick conduit, by gravitation.

From these circumstances, none of the London works are good examples of the type now under consideration ;

but the following description will explain the nature of the works required for the utilisation of such a source as the Thames above London.

First of all, then, provisions must be made to meet the difficulty of the water arriving at the intake in times of flood in a state of great turbidity or muddiness. This is met by the provision of large reservoirs, which are always kept full so long as the water is coming down in good condition, and the inlets into them from the river are closed, and they themselves are drawn upon when the water of the river is turbid.

These reservoirs used to be of smaller capacity than at present, and were worked as subsidence tanks, that is to say, the water (which might be somewhat turbid) was let in at one end and drawn off only from the surface at the other, the suspended matters causing the turbidity subsiding to the bottom during the water's slow passage through the tanks.

In London, since the works of the several companies have come under the official supervision of Sir Francis Bolton, very large sums of money have been spent in increasing the efficiency of these subsiding tanks, by greatly augmenting their capacity, and practically changing their character into that of storage reservoirs.

In some of the works, these reservoirs are constructed at such a level that the water from the river flows into them by gravitation ; in others they are elevated above the ground, and the water is pumped into them. In either case it is next delivered on to the filter-beds, the construction of which is shown very clearly in the most interesting pavilion erected in the Health Exhibition by the water companies. These filters consist of reservoirs or tanks, made either by excavation in the ground, or partial excavation and partial embanking, as circumstances may dictate, having their sides sloped and pitched, or of vertical brick, stone, or concrete walls. The bottom is formed in many different ways, but it is always furnished with a number of open-jointed or perforated pipes or drains into which the water can pass, and by which it may be conveyed away to a pure-water chamber or pump-well. Upon this floor the filtering material is placed, and consists of clean stones, flints, gravel, shells, and sand, arranged with the largest sized material at the bottom and the finest at the top.

Probably the oldest style of filter shown in the Exhibition is that designed by the late James Simpson, C.E., for the Chelsea Company, and it contains all the materials above mentioned, and has a total depth of 6 ft. 3 in.

As, however, the really operative and effective portion of the filter is the sand, modern practice is tending in the direction of diminishing the depth of filtering material, and of omitting entirely several of the strata originally used. For instance, the New River Company's engineer exhibits a filter composed solely of 2 ft. of sand, resting upon 6 in. of gravel, the total depth being only 2 ft. 6 in. In working the filters, the water is brought from the storage or subsiding reservoir on to the top of the sand, and stands from 2 to 3 ft. above its surface. It then percolates downwards through the filtering material into the drains below, and is run away to be pumped for distribution.

The speed of filtration may be adjusted by the head under which the filter is worked, that is, the difference in level betwixt top water and the draw-off. In some cases this is only 2 or 3 in. The speed at which the water should pass vertically downwards through the sand used to be stated as 6 in. per hour, which gave 675 gallons per square yard per day of 24 hours, but the London companies are now not filtering more than 450 to to 500 gallons, or from 4 to 4½ in. per hour.

The matter which is arrested by the filters consists principally of finely divided mineral matter washed from the surface of the land, of some vegetable and a trace of animal matter. These impurities are caught almost entirely in the top half-inch of the sand, which in course of time they choke and render impervious. The filter is then put out of use; the water is drawn off, and a skimming of the fouled sand is carefully removed and washed in apparatus which separates the light muddy matter and leaves the clean sand, which is again put upon the filter. Of course, the washing process involves some loss of sand, and periodically additions have to be made of new material. After filtration, the water is in a fit condition to be pumped and distributed to the consumers.

Thus far we have been dealing with "above ground" sources of supply, obtained either by gravitation or by artificial pumping, under the four heads numbered—(1) being springs at high elevation, without storage; (2) being surface water from moorlands drawn from natural lakes; (3) being surface water from similar watersheds, impounded in artificial reservoirs; (4) being river waters filtered, and artificially pumped for supply.

There are in this country a few examples of hybrid schemes, that is, where water from comparatively low agricultural land is impounded in large reservoirs, and where it has to be subsequently filtered and pumped for distribution in the district. There may also be cases where water collected at a sufficient elevation to supply a town by gravitation has to be filtered before delivery.

We now come to the underground sources of supply, and one or two examples will suffice to explain how these are made available. We need not go far from home to learn all about one of the most important of these underground sources, for it lies under our feet in the chalk forming one great feature of the London basin.

London is actually built upon the tertiary deposits, which consist of Bagshot sands, London clay, and the sands and mottled clays of the lower strata; but underlying all these is a mass of chalk having the southern edge of its outcrop on the north of London about Hatfield, and the northern edge near Royston, and its southern outcrop extending from Croydon to Mersthan. On the west the chalk reaches as far as Devizes, and on the north-east to near the coast of Norfolk and Suffolk. Portions of this vast area are no doubt covered by impermeable drifts of varying character, but there is still a very large tract of country upon which the rain which falls sinks below the surface, and goes to charge the great underground chalk reservoir below.

Possibly, the term "reservoir," though a common one, is a little misleading as applied to the chalk, because for water supply purposes, a large proportion of that which percolates into its mass is not recoverable by ordinary means. It is the water which circulates through the cracks and fissures which is really available, and not that which is held in the minute capillaries of the mass. Some chalk will contain 20 per cent. of its own bulk of water, and yet will not yield a drop of this under ordinary conditions.

Of the water which thus sinks into the chalk, a large portion finds its way out again into the bed of the river, another portion appears in the shape of large springs, such as those at Carshalton and Croydon, which go to form the river Wandle, by flowing over the edge of the impervious tertiaries

Very rarely are there any streams where the chalk itself comes to the surface, but after heavy and continuous rains, streams do appear and flow for a time, and these are known as "bournes." As the chalk is 500 or 600 ft. thick, a very large quantity of water is, however, left in it below the level of any of these natural outlets, and this water can be obtained in London by sinking wells through the overlying impervious beds of London clay, and allowing the water to rise, as in an Artesian well.

There are a large number of wells in the London basin, and one of the metropolitan water companies, the Kent, obtains its supply exclusively from such wells. The ordinary practice is to sink a well from 5 ft. in diameter upwards, and line the same either with brickwork or cast-iron cylinders down to the chalk. This will pass through superficial gravels, blue clay, bands of sand, mottled clay, &c., and sometimes on the top of the chalk a band of flints will be found. Below the bottom of the well a boring is then made from 4 inches up to 15 or 18 inches in diameter, and lined with iron whilst in soft or much broken chalk, and left unlined where the material is more compact.

In those parts of London which are not elevated many feet above the level of the river, the water rises to very near the surface of the ground, and in some cases overflows; but wherever large quantities are required, resort must be had to artificial pumping so as to lower the level of the water in the well, and thus open out a larger cone of exhaustion in the chalk. Favourably situated chalk-wells yield as much as 2,000,000 to 3,000,000 gallons a day.

In many cases wells and mere borings have been put down right through the chalk to the upper greensand or gault below, and have yielded only a very small quantity of water. This arises from the fact before referred to, that the water circulates freely only in the cracks and fissures, and if some of these are not cut into by the boring, little water is obtained. The most certain way, therefore, of ensuring a supply from the chalk, is by sinking a well down to below the permanent level of saturation, and then driving headings or adits in various directions, for the purpose of reaching some of these fissures. Many of the towns along the south coast of England are supplied by works of this character. It has been found that where the chalk of the South Downs has been undisturbed and is unfaulted, there are large vertical fissures which run, broadly speaking, from north to south, that is, at right angles to the coast. Along these fissures the water travels freely, and has its outlet at the base of the cliffs on the coast, and may be seen running down the beach in many places into the sea.

Parallel to the coast, the water is found to lie with its surface nearly horizontal, because of these permanent outlets; but on lines at right angles to the coast, the surface of the water rises rapidly inland, on a nearly uniform slope, so so much so that, at six miles from the coast, it stands more than 200 feet above mean tide level. Advantage has been taken of these conditions at Brighton, and other places similarly situated, to sink wells and drive headings parallel to the coast, at about the level of low water.

At Brighton there are two such stations, one at Lewes-road on the east, and another at Godstone Bottom on the west. These wells are both about a mile and a quarter from the sea, and headings are driven to a total length east and west, from Lewes-road, of 2400 feet; and at Godstone Bottom, of 1300 feet. In the first case, fissures are met with about every 30 feet, but as a rule these are small, and do not yield more than 100 to 150 gallons a minute. In the latter they are further apart, but some of them yield 700 or 800 gallons a minute, or over a million gallons a day. This water, being intercepted by the headings, is led to the respective wells, where, by means of suitable steam machinery, it is pumped up to the several service reservoirs supplying the different zones of the town.

The water so obtained requires no filtration. It is bright and sparkling, but of necessity hard, and although not objectionable for dietetic use, is not well fitted for cooking or cleansing purposes, and would be utterly unsuitable for the manufacturing processes of Lancashire and Yorkshire, though thoroughly well adapted for paper making.

In addition to the chalk, good supplies of underground water are obtained in the South of England from the Hastings sands and the oolites, and in the north from the new red sandstone, magnesian limestone, and other formations; but in all cases the works required for the utilisation of these sources are very similar, consisting of wells, borings, and adits, with competent pumping machinery.

Comparing very generally "above-ground" supplies by gravitation with "under-ground" supplies involving pumping, there are advantages and disadvantages on both sides, which may shortly be summarised as follows :—

"ABOVE-GROUND" GRAVITATION SOURCES.

Advantages.	Disadvantages.
1. No pumping.	1. Distance from place to be supplied.
2. No filtration.	2. Peaty stain.
3. Softness.	3. Costly and somewhat risky impounding reservoirs.
4. Low charges for maintenance.	4. Large works involved to provide water "compensation."

"UNDER-GROUND" PUMPING SOURCES.

Advantages.	Disadvantages.
1. Proximity of source to place to be supplied.	1. Annual charges for pumping.
2. Low first cost.	2. Hardness (generally).
3. Few structural contingencies attending works.	
4. No filtration.	
5. No compensation for abstraction of water.	

DISCUSSION.

Sir ROBERT RAWLINSON, C.B., said the suggestion of Mr. Easton with regard to supply by meter for large consumers and trade purposes was one of great interest, not only to the public of London, but to the outside public generally. The whole point would turn on the possibility of supplying a reliable meter cheaply, when he did not think a system of supplying water by meter would be objectionable. The great abuse at present in the supply of water for domestic use, under high pressure, was the intolerable waste which took place, which made it almost impracticable to keep up a supply of water at a moderate cost. In the metropolis the supply was equivalent to about 32 gallons per head of men, women, and children, and it needed no great reasoning powers to see that there must be in that vast supply a great deal of waste, for no such quantity could be used legitimately. Some of it the tenant was not liable for, being lost by leaks in the mains ; some was lost by leaks in the service pipes, but a great deal was lost by having fittings out of order, and services deliberately left open to flow during the night. That tended to prevent a constant service, and, therefore, he should not object personally to seeing water sold by meter. In another paper the word "pure" had been applied to certain gathering grounds, such as the great moorlands of the country, which were supposed to give a pure supply of water, but this was a great mistake. There was no pure source of supply, as when water came in contact with the earth, even on the mountains of Scotland, which gave a very soft water, they were covered with vegetation up to their summits, and were inhabited by different animals and birds, and whatever the value of that water might be as soft water—and it had its value—for domestic purposes it was very dangerous, especially to strangers. People coming from England to the highlands of Scotland were almost certain for the first few weeks, if not longer, to be attacked by diarrhœa. He spoke practically, because he and his family had suffered from it ; when he was down at Ballater, some time ago, he spoke to the commanding officer at the station where the military were brought down when the Queen was in Scotland, and he learnt that invariably when the soldiers were brought there one-half of them suffered from the softness of the water, and something it contained, which was washed from the mountains. The medical officer also told him that strangers were frequently obliged to leave the district on account of the effect that the water had upon them. A great deal was said against water taken from the Thames, and he was not going to advocate impure water or hard water, but he had had to study the question as a practical engineer, in some respects philosophically, and as it concerned his own health. He had lived three times in districts supplied with what was termed pure soft water, and his experience there had made him very glad to get back again to so-stigmatised polluted Thames water. Even for washing, for which soft water was so much prized, he had more pleasure in washing in London water than he had in the lake waters, for if you used soap—and you could not clean yourself thoroughly without it—you had the greatest possible difficulty in keeping sponges and things about the toilet table clean, because the soft water would not easily take the soap out. You might get water from tube sinkings, and deep wells, but you did not then get pure water. The late Dr. Angus Smith—and no one had paid more attention to the qualities and character of water than he had—said that if you gave him the analysis he could tell the stratification the water came from ; and, on the other hand, if you gave him the stratification he could predict the character of the water which would come from it. And that must be so because water as it fell from the clouds was soft water, the purest water in nature, and it was a powerful solvent. It dissolved and combined with any of the salts that it came in contact with. He often regretted that persons travelling in Africa, or in any country not previously traversed by civilised man, that they did not describe the appearance of the rivers and lakes more particularly, and mention whether the water was brown, or what character it had. If you saw a river running bright and sparkling, you might put it down as coming from a limestone source ; if it were running bright and brown, it came from a primitive source, slate or granite. Of course when rivers were in flood and turbid, you could not predict anything about them. Water to be used for domestic purposes required special care in treatment and in storage. When a river is the source, the water must be filtered: as from the Thames, the Ganges, and the Nile. Deep well water, from chalk, new red sandstone, or from the oolites, must be stored in covered reservoirs ; as if exposed in open reservoirs to sunshine and air, such waters become polluted to a worse degree than river water filtered.

Mr. EDWIN CHADWICK, C.B., said sanitary science had still to be applied to the instruction of engineering science in this matter of water supply. Originally, he did not object to soft water supplies, for in the then state of knowledge it was stated that the main infusion to which they were liable was from the peat, and a certain amount of tannin, which was not thought particularly injurious; but subsequent experience had shown there were further objections, and he did not think Sir Robert Rawlinson had stated them sufficiently broadly. Very soft waters, the surface washings of moorlands, were in use in Manchester, in Glasgow, and also in Dublin. He had received particular results of the soft water in Glasgow for nearly three months, and found the infusion of peat rendered it unfit to drink, as it produced dyspepsia. In Manchester, the peat-tainted water had the same effect, and he believed the same occurred in Dublin. In Manchester, it not only produced dyspepsia, but had such an action on lead piping as to lead to a large amount of lead poisoning. There was no doubt that in those places the water was not fit to drink during a certain portion of the year. He found that in Glasgow it was customary at some hotels to use glasses coloured, so as to conceal the colour of the water which was supplied. In the face of such experience, what was to be said of the proposal to bring to London 200 gallons per head of peat-tainted water—which for two or three months in the year was not fit to drink? At that time, Clark's process had not got farther than the reduction of hard water to 8°, but now it could be reduced to 4 or 3½, and in those localities, such as Canterbury, where first hard spring water had been thus softened, it produced the finest water possible, which delighted the consumers not only for drinking, but for all domestic purposes. He looked forward to the time when the supply of water would be reduced as it was in Manchester, Sheffield, and other places, to some 17 gallons per head per day. It might certainly be reduced by half, and if that were accomplished, it would reduce the intakes very materially, and also the establishments of the water companies, and this would be further aided by the chalk sources being utilised. It should be remembered that the Board of Health, some years ago, directed an examination of the spring supplies near the metropolis, and it was found that some 40 million gallons of water could then be drawn from perennial springs in the Surrey sands quite free from every objection, in fact free from the greater amount of impurity which was collected by rain water. The consumption then was not more than 18 gallons per head of population, and it was demonstrated in various ways that fully three-fifths of the water now pumped into London was actually mischievous, supersaturating the subsoil with additional rainfall, and he believed that evil was still going on, and would continue until the supply was put on a public footing. As to the qualities, they depend mainly on its aëration, which the stomach test, and not chemistry, determined. Water direct from spring sources in chalk was highly potable ; taken from cisterns in which it has stagnated, it was charged with bad town air ; taken from a slum in which it has been kept, it was charged with the foul air of the slum. Chemistry does not analyse such air, but the stomach does. The prisoners of Millbank Penitentiary had their supplies of water changed from a river source to a spring source, and the medical officer showed that the change was attended by a great improvement in health. Death-rates were adduced to show differences in the qualities of water ; but the fact was general that the people of the wage-classes drank, not water, but beer and tea : only children drank water. Not engineering, but sanitary science took cognisance of the principle of circulation against stagnation. In none of the papers did he find any due recognition of the conditions of stagnation which made good supplies bad, and bad supplies worse ; in none was there any recognition of the effects of self-cleansing house drainage, which discharged sewage fresh and undecomposed, in conditions which fed fish, and the conditions of stagnation and putrescence which killed fish.

Mr. BISCHOF said the germ theory had been referred to in one of the papers, and it almost appeared as if the authorship of that theory were imputed to Dr. Frankland. He was sure if that gentleman were present he would be the first to disclaim that idea; he had simply adopted that theory as being the one most in accordance with observed facts. He was under the impression that Mr. Mansergh's paper must have been written some time ago, or he should have expected him to go a step further, and refer to the memorable discovery, by Dr. Koch, of the comma or cholera bacillus. He did not go so far as to consider it finally proved that this bacillus was actually the cause of the cholera, but he thought it extremely likely that the further researches of Dr. Koch and other scientific men would prove that to be the case, and then, perhaps, Dr. Tidy's incredulous gaze might behold the germ itself.

Mr. MAXWELL said he wished to refer to a passage in Mr. Denton's paper in which he said that the deficit of the present year would have been more severely felt had it not been, in some measure, counterbalanced by the excessive rain which occurred during the last seven years, which left a balance to be carried over. But as far as his experience of underground water went, he did not consider that they had a bank to fall upon, or that the rainfall in previous years affected the present in the slightest degree. In the waterworks with which he was connected in the neighbourhood of Hull, which was a supply from the chalk, the wells followed very nearly the average rainfall of the three previous months. Thus in considering their present supply, he had to look at the rainfall of April, May, and June, and depend entirely upon it. Certainly, so far as the water which fell on the Yorkshire wolds was concerned, it found its way into the Humber and German Ocean, and they never could keep any stock. Mr. De Rance had advocated dummy wells, which should be fed in rainy seasons to keep up the reservoirs for dry seasons, but he was satisfied that, in his district, they would be no use. He had a peculiar instance of that three years ago, when there was a heavy snowfall about February. The water in the shafts came up as a rule at a temperature of 50°, but in the June of that year it fell to 46°, which he could not account for until it occurred to him that it was owing to the snows, which lay a long time on the ground and then gradually melted. Mr. Latham had referred to the rapidity with which the water level fell last year, which again was an illustration of there being no storage of previous years to fall back upon. Last year, in June, there were 30 feet of water in the bottom of his shafts, in July it fell to 20 feet, and in Sepember to 7 feet. This year it came down, in May, to the same level as it was last year in August, simply because after January, which was a wet month, there came February, March, and April, exceedingly dry. He was quite satisfied that the rain of previous years was not stored up as had been suggested.

Mr. E. K. BURSTAL said he was sorry to differ from Mr. Easton with respect to the supply of water by measure, but his experience of ten years in the management of large works led him to a totally opposite conclusion, mainly on account of the expense. Taking a town of 100,000 inhabitants, one meter would be required to nearly every house, and supposing there were five persons to each house, that would require 20,000 meters, the cost of which, including fixing, would be £100,000. At five per cent. that would mean an annual charge of £5000, and he knew that an inspector could not possibly look after more than 1000 meters, so that £500 more must be added for their wages, and £5500 was a large sum to charge on such a town. Now the saving, he calculated, would not be as much as £500 a year. When he took charge of the Oxford Waterworks about five years ago, he had a similar experience to what he previously had at Derby. Oxford was using 42 gallons of water per head per diem, but he had now brought it down to almost exactly 20. A few nights ago, being desirous of learning more particularly the quantity of water used at different hours of the day, he had the whole town supplied from the service reservoir, which he had carefully gauged, and found that from twelve o'clock at night to four o'clock in the morning, when no water was really used, for there were no manufactories there, the quantity wasted was equivalent to 6 gallons per head. He could safely say, therefore, that 14 gallons per head only was used, and 6 gallons wasted. He had already reduced it from 42 gallons to 20 gallons per head, by means of two inspectors, who had various other duties to perform. That was in a town with a population of 45,000. At Derby, with 75,000 population, he had three inspectors, and if that could be done, he thought there was no necessity for the enormous expense which would be incurred by introducing meters. Meters for measuring water were very different to gas meters. With gas you had a pressure of inches, but with water there was pressure from 150 feet to 200 feet, which made it very difficult to keep any instrument absolutely in order, and there were always disputes with reference to them. The only meter which he knew of which was a good type of a positive meter was Kennedy's, but the great objection to that was that it often let the water pass through it day after day without registering it at all. He certainly had had one in use ten years, which was never touched except to oil it, and at the end of that time it was as perfect as at the beginning ; but he had had them in other places where they were often a source of annoyance. Parkinson's was very good, but it was only a low-pressure meter. Siemens's was also good, but the public did not like an inferential meter ; and, in fact, there was no meter at present which would really answer the purpose, and he was quite certain their introduction would be very distasteful. In London, a reduction in the quantity consumed could easily be brought about, and the companies would be the first to co-operate, but it was necessary for the public to assist ; and, unfortunately, at the present time, any one who could oppose the water companies in the police-courts and elsewhere was the popular man, and probably that would be so until the whole of the water companies were transferred to some public authority, and then it would be the old story of Stockton and Middlesbrough over again.

Mr. JABEZ HOGG remarked that London was a very exceptional city to deal with. It was useless to point out what had been done by provincial towns, and this constituted a very serious impediment in the way of procuring a better water supply. In the first place, it would not do to ask the Government to sanction any scheme which would make London dependent on one source of supply; and, therefore, the proposal to bring water from Wales, or from a long distance, was out of the question. If there were an aqueduct bringing water from Wales, what would happen to London if some of the dynamite people determined to cut off the supply? Besides the danger there was the enormous expense. Then there came the question of how could we get a better supply than that from the Thames and Lea, for he apprehended no one would say that either of those rivers afforded London a pure and wholesome supply of drinking water; the late discussion in the press made this appear impossible. The water companies had also been accused of taking more water than they should take, thus leaving the river-bed in an exposed and dangerous state; exclusive of this, there were a million inhabitants living on the banks of the Thames, and he was surprised the Thames Conservancy should adhere to the statement that the water was comparatively pure, and free from pollution. It was said, indeed, that twenty-one towns situated on the banks were still continuing to pour sewage into the Thames. That was a statement which could hardly be denied. They certainly did not pour the whole of their sewage into the river, but a great portion of it found its way, secretly or openly, into the Thames. If any one would go up the river with him, he could point out innumerable inlets where sewage water made its way into the river, in spite of the efforts of Conservators.

Mr. E. K. BURSTAL said that was not the case above the intakes of the London water companies.

Mr. JABEZ HOGG said it could not be controverted that the Thames was miserably polluted above the intakes of the water companies. He would not throw blame upon the Conservators; they did their best; it was simply impossible to divert the sewage of the immense population residing on the banks of the Thames; and even taking it that the sewage went through a sewage farm, or was submitted to the A B C process, the effluent water must pass to the Thames, and was dangerous to health—not always dangerous, but supposing two or three cases of cholera were to occur high up the stream, and the dejections sent into the river, there would be the extreme danger of everyone becoming affected by cholera who might partake of the water. It had been said that the present deficient supply of the Thames might be supplemented by impounding underground water; indeed, one of the water companies obtained a considerable quantity of spring water from the gravel and subsoil, but he denied that this was pure water. With regard to the Lea, there was a letter in the *Times* that morning stating that it was shamefully polluted, the sewage farms on its banks sending in effluent sewage, most dangerous to health, and this could be seen by anyone at the trouble to go up the river. He contended it was impossible for London to look any longer for a supply of drinking water to the Thames or the Lea; there should be an immediate resort to deep well water, which could be had in unlimited quantities from the chalk, where it had been stored up for ages. It was said, however, this water was too hard; it was no doubt discreditable to rich companies to send hard water to their customers without softening it by a process which could be carried out at a small cost in their reservoirs. He considered it a great discredit that a rich company, like the New River Company, should, after sinking deep wells into the chalk, pump a very large quantity of good spring water into a river exposed to pollution, and send it on, open canal fashion, to London, or otherwise keeping it in large open reservoirs where it may become stagnant, and men and dogs may drown. It was impossible to purify such water as that, and convert it into pure and wholesome water such as the companies engaged to supply. The water he drank had 16 degrees of hardness, which was sufficient to produce a large amount of calculous, a disease which he believed was very much on the increase, and besides which it did damage, and marred all domestic arrangements. Mr. Easton had spoken of the damage done to water by cisterns, but he contended that much less damage was done in that way than was alleged. He had gone very carefully through all the poor districts of St. Giles's, and visited house after house to see the condition of the cisterns, and he found that it was less due to the condition of the cisterns than to the quality of the water sent into them. He had just had his cistern cleaned out, and found a very small deposit in it; but of course his remarks applied to covered cisterns, and not to the uncovered cisterns found in some of the poorer houses. It was impossible, with the short supply of water the companies gave, for the poor people to do without cisterns altogether. He was often without water on Sundays, because a short supply of fifteen or twenty minutes daily was thought sufficient by the company.

The CHAIRMAN said he must say a word in support of Mr. Easton's statement with regard to the cisterns. He thought Mr. Hogg would have to inform himself a good deal more with regard to the real condition of cisterns in London, before speaking so decidedly as he seemed inclined to do.

Captain E. BURSTAL said he had only just come into the room, but had heard some astounding remarks, and he was quite sure Mr. Hogg must have been very much misinformed as to the real condition of the river Thames above the intakes of the water companies. That afternoon he had deposited in both Houses of Parliament a report for the year ending December, 1883, signed by the Chairman and himself, which no doubt would shortly be published, when it would perhaps be seen that there were but two towns on the banks of the Thames which passed any pollution into the river. One of these towns was Staines, and they were now beginning to do what they had had notice to do some time ago, and what they had been prosecuted for not doing, namely, adopting some system to deal with their sewage. The other town was Henley, from which a very small quantity of sewage found its way into the river, but however small it might be, it was the duty of the Conservators to arrest it, and do everything they possibly could to prevent any pollution, and every source of pollution which had been found above the intakes of the water companies had been stopped.

Mr. HOMERSHAM said he had seen sewage from the outfall at Windsor, of a most disagreeable nature, coming into the Thames. The fact was, every drop of liquid sewage now went into the Thames; he agreed it had passed through some treatment, but if anybody contended that urine, one of the most deleterious matters that could go into water, was thereby purified, he was grossly mistaken. The sewage was purified to some small extent; but to say that no sewage entered the river, when the whole of it went in except some solid matter, was not correct. He should like to ask particularly about Reading as well as Windsor.

Mr. E. K. BURSTAL said he was the engineer who carried out the Windsor sewage arrangements, and after the precipitating process, the whole effluent was passed through land.

Mr. WALKER said he was manager of the Reading Waterworks, and had a great deal to do with the sewage works of that town. The sewage did not go into the river Thames. Reading had expended over £300,000 in diverting the sewage of the town from the Kennet, which was one of the principal tributaries of the Thames. But while Reading had done that, the sewage of Newbury, sixteen miles above the intake of the Reading Waterworks, went into the Kennet, and from thence might find its way into the Thames. From what had passed that day, he felt quite at a loss to know what would be the best source of supply;—one recommended getting it from the chalk, and then they were told the water was too hard; and if they got it from the rivers, that was too soft. With reference to the sewage of Reading, he had simply to say that it had not gone into the Kennet for the last seven years.

A GENTLEMAN asked where it did go to.

Mr. WALKER said it went to the "Manor" Farm, and the effluent flowed into the Kennet.

Mr. ROBERT SUTCLIFF said Mr. Denton, in his paper, mentioned some supposed disadvantages attending the adoption of tube wells, namely, that if an accident happened to the pump, the supply was stopped until it was replaced, and that if the supply was insufficient, another well had to be constructed. As these points were important to the system which he had the honour to be connected with, he wished to say a word or two upon them. With regard to the first, if a pump got out of order in an ordinary dug well, as a rule, another pump must be put up in its place, but in a tube well that could be done in a few minutes. With reference to the supply running short, he could mention one town (Watford) in which some time ago they doubled the supply, their dug well having got into the very position which it was supposed the tube wells might get into, and not giving a sufficient supply; they put down a single tube well of 8½ inches, and that gave double the supply previously obtained. In reality, having to add other tube wells has really in many cases been an advantage. Sometimes people would say they did not want to incur a great outlay at present in order to provide for future possibilities, and by having a tube well they could have a supply requisite for the present which could be added to as it was wanted. If more water were required, all they had to do was to sink two or more tube wells, and couple them to the existing arrangement. Being at the present time engaged in some ten deep Artesian borings, he might make a remark on the general question. There seemed to be a great difference of opinion as to whether water, after it was purified, was prejudicial or not, but he always felt that he would very much rather have water which had not been contaminated, even if the contamination were afterwards removed. His idea was to get the water pure, and keep it pure, not to allow it to be contaminated, and then put it through a process of purification, which seemed to him to be objectionable and contrary to common sense. On the banks of the Thames, in many places, the sources which supplied the river were beautifully pure, and though he did not approve of shallow sources as a permanent supply, yet, temporarily, an enormous quantity of pure water might be found on the banks of the Thames, which went to add to its volume. In one case, even at Gravesend, within a stone's throw of the river, which was then in a most disgusting state, having put down a tube well, he had water which was analysed, and pronounced to be as pure as that of Loch Katrine. There was a vast body of this water flowing towards the Thames, and if it could be taken temporarily, it would save the water companies a great expense in filtration. This reminded him of the manner in which water was filtered. He did not know whether any of the water companies had tried passing the water up instead of down, but it seemed to him very objectionable to let all the stuff they were trying to prevent passing, be caught on the surface of the filter-beds, and let all the other water go through that. He thought the right system was adopted by one of the filter companies, in which they made all the water pass upwards through the filter, so that any sediment which might be deposited was left at the bottom, and could be easily removed.

Captain DOUGLAS GALTON, said with reference to the observation of Mr. Hogg that cisterns were not objectionable, that, if one thing seemed to have been better established than any other with reference to the water supply, it was the danger of cisterns. He did not say that cisterns might not be kept clean, but the general plan was to leave them for weeks, months, or years, without being cleaned, and then it was undoubted that however pure might be the water put into them, it would become contaminated. All who had studied sanitary matters had come to the conclusion that if possible a constant supply was the best thing to obtain, and that such a supply would obviate the necessity for house filtration. Those impurities which were now obtained in London water were chiefly owing to the method of storing it.

Mr. HOGG said what he wished to imply was that the water supply was so short that the cisterns were drained dry every day, and therefore there could be no sediment.

Mr. CHADWICK said, living at Richmond, he had seen water running from market gardens into the river in enormous quantities, the colour of coffee, and he had gone to take a bath there, and found the water absolutely smell of manure. Many people forgot that it was not sewage alone, but the surface washings from lands heavily dressed with manures, which polluted the rivers.

Mr. EASTON said he laid so much stress on the evils of the cistern system because, when he investigated the water supply in 1877 and 1878, an immense mass of information was got from the Metropolitan Board which would have been laid before a Select Committee if the Bill had not been stopped at the second reading, and very conclusive evidence was obtained as to the filth in the cisterns. Five of the ablest chemists in England, with the Chairman at the head of them, were engaged for three or four months, not only investigating the quality of water supply in the mains of the different companies, but the mud which they took out of the cisterns, and however difficult Mr. Hogg said it was to find any deposit, he could assure him there was an ample supply of taint from all parts of London —not only from the poorer class of houses, but they found it in places where it certainly ought not to have been found, and where, if the people took proper care of the cisterns, it certainly would not have been found. With regard to the people generally, it was their misfortune that the cisterns were in such a condition; it was a consequence of the intermittent supply that this filth would accumulate. He might add that they were investigating not with a view to prove that the water in the mains was the best, but on behalf of the Metropolitan Board of Works, who had a rival scheme, so that, if they had any bias, it was to show that the water in the mains was bad.

Mr. MACKNIGHT said there had been a great deal of discussion in Edinburgh on this question of cisterns. The Water Trust were under the necessity of bringing in a very large supply of additional water, and it so happened this was from the Moor Foot Hills, ten or twelve miles south of Edinburgh, where there were no springs ; and there were loud complaints on the part of the artisans of its impurity. The Water Trust in defence got up a cry about the state of the cisterns, but they were completely beaten. Most of the houses in Edinburgh were what are called self-contained, and all had separate cisterns, which the owner took care to keep in good order, but the bad water sent into them left a deposit. All chemists knew very well that if water had certain mineral ingredients in it, after standing a short time, it would leave a deposit, but that was due to the water, not to the cisterns.

CONFERENCE ON FRIDAY, JULY 25TH, 1884.

II.—QUALITY OF WATER. FILTRATION AND SOFTENING.

Sir FREDERICK ABEL, C.B., F.R.S., in the chair:—

The CHAIRMAN, in commencing the proceedings, said the outcome of the previous day's discussion showed that there was agreement, at any rate, on some important points. All agreed that the water supply was derived from rainfall, though perhaps, with the exception of Mr. Jabez Hogg, who spoke of the illimitable supplies stored in the chalk. The importance of the systematic observations introduced by Mr. Symons, and the value of the data derived from those observations as indicating the relative abundance or scarcity of the supply of water in different districts, and their relation to the population of the districts, were also unanimously recognised. In connection with this matter very useful information had been supplied by Mr. Topley, Mr. De Rance, and Mr. Whitaker, and the maps prepared by the latter gentleman promised to be extremely valuable. There could be no doubt that a combination of careful hydrogeological surveys, with a study of rainfall observations throughout the country, would serve to enlarge our knowledge with regard to the conditions to be fulfilled for securing an efficient water supply to different parts of the kingdom. It was only natural that the discussion with regard to the sources of supply should gravitate towards the larger towns, and more especially towards the supply of water to London, which had been of late a question of such serious controversy. Mr. Bailey Denton, however, in his interesting communication, had referred more especially to the supply of rural districts or small communities; and it might be hoped that the disinclination of local authorities, to which he referred as having stood in the way of progress, was rapidly disappearing. There could be no question that the country generally was now thoroughly alive to the necessity for obtaining for all communities, large or small, as pure a supply as could be obtained. In connection with this subject, Mr. Denton gave interesting information with regard to the application of tube wells; he might say that in connection with military matters he had had considerable experience of the usefulness of such wells, and so long as it was not necessary to apply power in connection with them, and a moderate supply only was required, their use would be attended with very considerable advantage. With regard to large towns, there was also a consensus of opinion to the effect that in order to ensure as pure a supply of water as possible, it should, if practicable, be obtained at its source, rather than after it had been more or less polluted by passing along streams and receiving surface drainage or still more objectional matters in its course. With the exception of Mr. Hogg, he also thought they were all impressed with the fact that the necessity not only for having water pure, but for keeping it until used in a perfectly pure condition, gave rise to a wide spread objection to intermittent supply, and to the consequent necessity of having tanks in houses, in which the water inevitably became more or less polluted. It was somewhat remarkable that Mr. Hogg, in his search for the minute animalcules on which he based such important conclusions, should have entirely overlooked the grosser impurities which everyone else found in the cisterns.

With regard to the supply from wells, Mr. Baldwin Latham had directed attention to two or three important points; for instance, to the necessity, in estimating the quantity to be derived from such a source, for ascertaining what was likely to be the minimum supply from those wells, and regulating the number of wells accordingly. There was no question that this might be a matter of considerable difficulty for water engineers to meet. He had also directed attention to an incidental point, which, as he (the Chairman) had pointed out, the Conference could hardly deal with, but which it was impossible to keep entirely out of sight, viz., the influence of wells in reducing the supply of water to streams in their neighbourhood, and the consequent questions of property which would arise. Upon the question whether the water supply should be taken from rivers or wells, there were great differences of opinion. Some believed that, although it would be most desirable to have water absolutely pure, yet there were considerations weighing somewhat strongly in favour of obtaining water from convenient streams, as high up the source as practicable, and to apply, in connection with such supply, the most efficient means of mechanical, and, if possible, chemical purification. Others took a somewhat poetical view with regard to the supply from deep wells, and utterly ignored the possibility of any contamination of such water, and seemed to think that you had only to sink any number of wells as close together as they could be placed conveniently, to obtain any amount of water to supply a town of any size. Those were points upon which differences of opinion would always exist until the matter was put to a practical test on a large scale. Again, many, in referring to the hardness of the water, said that companies had no business to give hard water; that they had only to adopt a softening process, which costs little or nothing; and that if a water company were allowed to supply water they should only supply it in the softest condition in which it could practically be produced. Of course that was a very natural demand from the point of view of the consumer, but it remained to be seen how, if they drew water from deep wells for the supply of London, a softening process could be carried out on the gigantic scale which would then be necessary. With regard to that point, they looked forward to have some valuable information given them by Mr. Homersham and also by Mr. Baldwin Latham.

WATER FOR DOMESTIC USE.

By S. C. Homersham, M.Inst.C.E.

Water for domestic use, and for distribution through pipes into dwellings in cities, towns, villages, and other places, should be derived from sources that afford adequate quantities at all seasons, characterised as being:

1. Wholesome for drinking, for culinary, and for other uses.

2. Soft without having the power to dissolve or injure lead, and well adapted for washing the person, for use in baths, and for use with soap.

3. Of a normal uniform temperature at its source equal to the average of the climate for the year, which in England differs but little from 50° Fah.

4. Well aërated, holding in solution eight or more cubic inches of gases per gallon, namely, about two of oxygen, six of nitrogen ; agreeable and refreshing when drunk.

5. Clear, transparent, colourless, bright, and, when seen in large bulk, pure blue, the natural colour of uncontaminated water.

6. Unable to cause a deposit or fur in the utensil in which it may be heated or boiled.

7. Free from organisms, animal or vegetable, living or dead, and any matter in suspension.

Water in its natural or normal condition characterised by all these seven qualities may be abundantly obtained in some portions of the globe. It abounds in parts of Brazil, in parts of New South Wales, and doubtless in other places. Such water, however is not abundant in the United Kingdom.

Here it is difficult to find a source that will yield a considerable quantity of soft water associated with the other six named qualities; or to find a source that will yield an abundant quantity of soft water associated with qualities 1, 3, 5, 7.

Water, inland, is all derived from rains that fall on the surface. Land, composed at or near its surface of sand, gravel, chalk, and some other limestone, absorbs nearly all the rain that falls upon it and stores in its pores the greater portion below ground. Other land, consisting of clay, granite, millstone, grit, and other impervious rock, absorbs hardly any of the rain or snow that falls upon its surface. For the most part it flows off the land into valleys, and forms brooks, rivers, or floods. Sometimes the rivers or floods are collected in natural impervious hollows or basins, thus forming natural lakes.

Sometimes artificial hollows or reservoirs, or lakes, are constructed in valleys to catch and impound river and flood water, to supply or feed canals, or to be stored for domestic use. Thus the sources from which water can be obtained for the supply of a population, or for manufacture, or other uses, are—

1. Brooks, rivers, and natural or artificial lakes. These may all be called surface waters.

2. Springs that often naturally issue from the sides of valleys into brooks or rivers, and other subterranean water stored in the pores of rocks below ground, may be collected above ground or by means of wells, bore-holes, and underground adits or tunnels. Such water may all be termed subterranean or spring water. Water, however, whether surface or spring, is all derived from rain falling on land, mostly on uplands or hills. All brook, stream, or river water ultimately finds its way by gravitation into the sea through uncovered channels, or rivers, that may be seen, and are often navigable, providing inlets and outlets for vessels from the land into the ocean, or from the ocean inland.

All deep subterranean water also ultimately finds its way into the ocean, through subterranean pores, fissures, or channels, often penetrating to great depths before doing so. Thus, at present, a bore-hole at Richmond, in Surrey, derives a supply from the surface carried down to a depth of more than a quarter of a mile below the surface of the ocean. The water from this bore-hole will naturally rise to an altitude of more than 120 feet above Ordnance Datum, or the mean level of the sea.

As a rule, for domestic uses, subterranean or spring water is greatly to be preferred to river or surface water, more especially when it is derived from certain beds of sand, as then the water often possesses the whole of the seven characteristics before described. Large quantities of subterranean water, however, are derived from the chalk formation in the south and south-east of England, and in Yorkshire, and used for the supply of urban and other populations. Thus a considerable portion of inner and outer London, and numerous towns situated on or near the chalk formation, are supplied by subterranean water absorbed by the chalk. Aylesbury, Brighton, Canterbury, Charlton, Deal, Dover, Greenwich, Gravesend, Hull, Margate, Plumstead, Ramsgate, Tring, Woolwich, and many other places, are entirely supplied by spring or subterranean water obtained in this way from the chalk formation. This water has five out of the seven characteristics I have mentioned, but is wanting in two, namely, softness and non-ability to deposit fur when boiled. By a simple process, however,—invented by the late Dr. Clark, and described in a paper read before the Society of Arts on the 14th May, 1856,—both the quality of hardness and the power to deposit fur when boiled are got rid of. The process is a simple one, and has now been in practical use for more than a quarter of a century with great success. Water so treated is greatly admired and valued by those who are supplied with it.

Surface water, whether derived from brooks, rivers, or lakes, though the latter be natural or artificial, is usually soft, and less liable to deposit a fur when boiled than most spring or subterranean water. On the other hand, it is not well adapted or so wholesome for drinking; (3) it is cold in winter and liable to freeze in distributing pipes; warm in summer, and (7) pervaded by numerous living organisms.

(5.) It is not always clear and bright without being filtered (2) and dissolves lead.

Thus, in these most important respects, spring or subterranean water is to be preferred to river, lake, or surface water. Those who care to follow this subject more in detail, will find both the quantity and quality of spring or subterranean water fully discussed in a paper I read before the Society of Arts on the 31st January, 1855.

It is obvious, also, that all brook, river, or lake water is liable to be greatly contaminated by becoming mixed with faded blossoms and fallen leaves; by mud, mainly composed of decaying vegetable matter and pervaded by numerous living organisms; by manure from off the land; by the excreta of fish, animals, and man, both liquid and solid, washed into it, and more especially in times of floods; by the action of frost and other contaminating causes that it would be difficult or impossible to prevent. Indeed, streams and rivers, in a greater or less degree, must always remain the sewer of a district, and the means by which surface washings are conveyed to the ocean.

All river, lake or surface waters, more especially in warm seasons of the year, are found to be pervaded by minute living organisms, vegetable and animal, none of which are found in uncontaminated spring water.

A paper read by Mr. Jabez Hogg, before the Society of Arts, on the 12th May, 1875, will be read with interest by those who care to pursue the subject.

In the Parliamentary Session, 1852, a body of householders deposited plans, and applied to Parliament for powers to supply a large portion of London with softened spring water at a very moderate charge for drinking and personal ablution, thus leaving the old-established companies who supplied the Thames water to continue the supply of such water for watering roads, for flushing sewers and closets, and for other gross purposes. At that time, however, the Water Companies had great influence in the House of Commons, so much so, that the Government of the day, very much, as I know, to their regret, felt themselves obliged to exert their influence to prevent the powers sought being granted, in order to secure the passing of a Government measure affecting Imperial interests.

As respects the metropolis, no physical difficulties exist to prevent the whole of the four millions of souls inhabiting the inner and outer circle from being copiously supplied with uncontaminated softened spring water, possessing all the seven characteristics I have named. Indeed, a considerable portion of the inner and outer circle is already supplied with uncontaminated spring or subterranean water, though not (2) of a soft character or (6) free from depositing a fur when boiled.

It is not from want of ability to supply the metropolis most abundantly with subterranean or spring water possessing all the seven characteristics that the inhabitants are not so supplied. The want of an uncontaminated supply to the greater portion of the inhabitants mainly results from want of the necessary technical information among these who have to put up with the present supplies.

Such Conferences and discussions as these we are now concerned with cannot fail to afford much useful information to many, and it is to be hoped will ultimately result in securing a more wholesome, a softer, and a cheaper supply carried into the dwellings of the mass of the population.

SOFTENING OF WATER.

By BALDWIN LATHAM, M.Inst.C.E., F.G.S., F.R.MET.SOC., &C.

FROM the remotest period of antiquity, of which we have any record, the art of softening water for the purposes of washing and cleansing, appears to have been known and adopted. Long anterior to the invention of soap, of which the elder Pliny gives us the earliest account, as having been first manufactured by the Gauls, caustic alkali derived from wood ashes, and from natural earths, was used as a lye. The process of making an alkaline lye was mentioned by Aristophanes (434 B.C.), and also by Plato (348 B.C.). We have also a record in the volume of Sacred Writ, in Jeremiah ii., verse 22 : "For though thou wash thee with nitre and take thee much soap." The Hebrew word *borith* used in this passage is stated by authorities to refer to the vegetable lye of potash, but in another passage of Sacred Writ, Malachi iii., verse 2, where reference is made to "fuller's soap," the Hebrew word *nether* is there believed to apply to a mineral lye or soda. The people of Egypt were known to use mineral alkali and ashes of plants for the purpose of making a lye for washing from an early period, as recorded by Pliny.

Nitrum, a natural lixivious salt which is found in many southern countries, was well known, and was used for washing at a very early period. Certain plants, too, the juice of which is of a saponaceous nature, were used in early days, instead of soap. Meal and many kinds of seeds and bran were also used in connection with washing operations. The urine of various animals kept until it became stale and alkaline was used in eastern countries at a very early period ; and in the Avesta, special directions are given for cleansing and purifying with the urine of the sacred cow. Pliny, in his 'Natural History,' states that if water be nitrous or brackish, or bitter, if some fresh barley meal is put into it, that within two hours it will be so amended and sweet that a man may drink thereof; and a translation made from Pliny, by Dr. Philemon Holland, in 1634, goes on to recount that the same operation of sweetening water may be effected by a kind of chalk which is found in the island of Rhodes; and a description of clay which is found in Italy will do the same. Pliny, who died A.D. 79, records the manufacture of soap as being composed of tallow and ashes, the best being made of goat's suet and beechwood ashes. That the amount of mineral matter in water, as affecting the conditions of health, was studied at a very early period, is known from the fact that the hydrometer was probably first used for the purpose of ascertaining the quality of the water used for dietetic purposes. Although the principle of the hydrometer has been ascribed to Archimedes, there is no record of this instrument having been made by him. The earliest record, according to Beckmann, appears from a correspondence between Synesius and Hypatia, the latter of whom was assassinated, A.D. 415, in which Synesius states that he found himself so ill that he proposed to use the hydrometer, and requested Hypatia to at once procure one for him. The mode of strengthening ordinary lye by the addition of lime was known in the time of Paulus Ægineta, a physician who flourished either in the 3rd or the 7th century.

Soap is mentioned by Geber in the second century, and at a later period is frequently referred to by Arab writers, as being used not only for detergent purposes, but also for external application.

Soap is very largely used, or rather wasted, in many places in the present day for softening water. It is now well understood that no useful effect in washing is produced until sufficient soap has been used to soften the water.

For the purposes of this investigation, water may be divided into two classes, hard and soft. *Hard water* is a water which contains salts of lime, magnesia or iron, and sometimes an amount of free carbonic acid. A hard water, commonly considered, is one that destroys soap in washing, while a soft water is one that does not destroy soap. A *soft water* may derive its properties from an absence of earthy salts, or it may have become soft by reason of the presence of certain alkaline salts in the water, notably the salts of soda and potash.

Hard waters may be divided into two classes, those which are permanently hard and those which are temporarily hard. It is often found that a single sample of naturally hard water partakes of both these properties. A water which is said to be temporarily hard becomes soft by boiling, as the hardness is due to salts of magnesia or lime dissolved in the water by the agency of carbonic acid, or due to the presence of this gas in a free state in the water. Under either circumstances, the effect of boiling the water a sufficiently long time is to drive off the carbonic acid gas. and a natural softening of the water takes place from the absence of this gas, and the earthy salts that have been held in solution by it in the water.

Water that is permanently hard derives this property from the presence of the same salts as render water temporarily hard, but instead of being combined with carbonic acid, they are combined with sulphuric acid, and to soften water that is permanently hard requires very different conditions than is the case with waters that are only temporarily hard.

The qualities of a good drinking water have been described as :—

1st. Freedom from vegetable and animal matter.

2nd. Pure aëration.

3rd. Softness.

4th. Freedom from earthy mineral or other foreign matter.

5th. Coolness and delivery at the minimum temperature.

6th. Lucidity or clearness.

7th. Absence of taste and smell.

Although many authorities insist that for the sake of health a soft water is beneficial, on the other hand, there are those who contend that there is no evidence whatever to show that even a hard water had any influence upon health. It is clear, so far as the health statistics of this country are concerned, that if anything the results come in favour of persons inhabiting districts having hard waters. On the other hand, it has been thought that particular diseases which affect particular localities, such as cretinism and goitre, are due to certain salts of magnesia, which have been found in the waters of the district. Some waters which are of remarkable softness, in which the softness is due to the presence of certain alkaline salts, especially those of soda, may be quite unfit for drinking purposes. A type of this water is found in the well supplying the Trafalgar Square fountains, as it is stated by some authorities that the large amount of soda contained in it, if taken habitually, acts medicinally upon the kidneys. It is also unfit for washing, as the water is liable to destroy certain colours, and stains glass. It is said to be unfit for bathing, as the soda combines with the oily matter of the skin, producing a roughness and liability of chapping. Water, however, which is naturally soft, or which has been softened by means of a process like Dr. Clark's, which does not add any new element to the water, has great advantages for many purposes ; it prevents incrustation of steam boilers and household utensils ; it results in a saving of fuel, less wear and tear in washing linen, and in the labour of cleansing ; it saves soap in all washing and cleansing operations, the water cleans better, and gives a better colour to linen ; and it is also stated to lead to greater economy in tea-making and brewing, but whether this is correct or not is very doubtful, as water used for such purposes is always boiled, and when used in that state should be as soft as softened water.

The processes which have been used both in ancient and modern times for softening water may be comprised under the heads of Boiling, Chemical Processes, Distilling, Exposure, Freezing.

Softening by Boiling.—Pliny, in his 'Natural History,' states that water that hath been once sodden, that is boiled, is far better than that which is raw. There is little doubt that the boiling of water, both as a means of reducing its hardness, and also to effect its purification, was very extensively practised in ancient times, and the practice of boiling water is still carried on amongst some of the older nations, such as China and parts of India, with the greatest possible advantage, both from an economical and from a sanitary point of view. The Emperor Nero (A.D. 50 to 68), both boiled water for drinking purposes, and subsequently cooled it in glass vessels to which snow was externally applied. The effect of boiling water is to liberate the carbonic acid which holds certain alkaline salts in solution, and on the liberation of the acid these salts are precipitated and forms the coating which furs our kettles, accumulates in our boilers, blocks the circulating pipes of our water-heating apparatus, and is often a source of danger, and always of expense. The effect of boiling water, in order to to soften it, can only be secured when this operation is sufficiently prolonged. The Commissioners appointed to inquire into the chemical properties of the water of the metropolis in 1851, made some experiments on the effects of boiling an artificially prepared hard water containing 13·5 grains of carbonate of lime per gallon, and it was found to decrease in hardness from 13·5 to 11·2 degrees by being heated to the boiling point; after boiling for five minutes, it was reduced to 6·3 degrees, for fifteen minutes to 4·4 degrees, for thirty minutes to 2·6 degrees, and for one hour to 2·4 degrees, so that the softening effect does not take place at once, but a prolonged boiling is required in order to produce the greatest degree of softening. In order to get rid of the temporary hardness of water, sharp boiling for not less than twenty minutes is requisite; but boiling water does not remove the hardness occasioned by the salts which are neutral; in fact the permanent hardness of the water is increased by boiling, as all the water evaporated leaves a concentration of the neutral salts in the remaining water.

It has also been shown that the alkalinity of water is more after boiling than when softening has been produced by an alkaline salt such as lime, but both have the effect of reducing the hardness to about the same degree. This increase of alkalinity after boiling is attributed to the concentration of the neutral salts consequent on the loss by evaporation. The temporary salts held in solution by water are precipitated by boiling, and it is these precipitated salts which cause the furring of kettles, hot-water boilers, steam boilers, and hot-water pipes, and have led to the adoption in certain cases of means either for retaining the salts in solution in the water or of preventing their deposit in steam boilers, but as a rule with only partial success.

Chemical Processes of Softening Water.—In a paper read before the Literary and Philosophical Society of Manchester in 1781, by Thomas Henry, F.R.S., a description is given of a mode of preserving sea-water by means of quicklime, in which the author pointed out that the earthy base of magnesia was precipitated in sea-water by lime, and its place taken by a calcareous salt. He also referred in this paper to the well-known action of quicklime on common water as a preservative. The effect of the lime, doubtless, upon the sea and fresh water was to induce abundant precipitation, which dragged down with it certain organic impurities, and as a consequence the water remained free from putrefactive influence afterwards, as was clearly shown in the course of his experiments.

The first patent for purifying water by chemical agency in this country was taken out in 1838, for precipitating by muriate of zinc and salts of soda, the latter salts precipitating the zinc from the water, leaving the water in a purified state.

In 1841, Dr. Thomas Clark, of Aberdeen, took out a patent for his well-known and beautiful process for softening water, and which has, more or less, been the basis of all other patented processes of this description which have been adopted since that period. Dr. Clark thus describes his process, in a paper published in the *Journal of the Society of Arts* of the 16th May, 1856:—

"In order to explain how the invention operates, it will be necessary to glance at the chemical composition and some of the chemical properties of chalk, for while chalk makes up the great bulk of the matter to be separated, chalk also contains the ingredient that brings about the separation. The invention is a chemical one for expelling chalk by chalk. Chalk, then, consists, for every one pound of sixteen ounces, of lime nine ounces, carbonic acid seven ounces.

"The nine ounces of lime may be obtained apart by burning the chalk, as in a lime-kiln. The nine ounces of burnt lime may be dissolved in any quantity of water not less than 40 gallons. The solution would be called lime-water. During the burning of the chalk to convert it into lime, the seven ounces of carbonic acid are driven off. This acid, when uncombined, is naturally volatile and mild; it is the same substance that forms what has been called soda-water when dissolved in water under pressure.

"Now, so very sparingly soluble in water is chalk by itself, that probably upwards of 5000 gallons would be necessary to dissolve one pound of sixteen ounces; but by combining one pound of chalk in water with seven ounces additional of carbonic acid—that is to say, as much more carbonic acid as the chalk itself contains—the chalk becomes readily soluble in water, and when so dissolved is called bicarbonate of lime. If the quantity of water containing the one pound of chalk with seven ounces additional of carbonic acid were 400 gallons, the solution would be a water of the same hardness as well-water from the chalk strata, and not sensibly different in other respects.

"Thus it appears that one pound of chalk, scarcely soluble at all in water, may be rendered soluble in it by either of two distinct chemical changes; soluble by being deprived entirely of its carbonic acid when it was capable of changing water into lime-water, and soluble by combining with a second dose of carbonic acid, making up bicarbonate of lime.

"Now, if a solution of the nine ounces of burnt lime, forming lime-water, and another solution of the one pound of chalk and the seven ounces of carbonic acid, forming bicarbonate of lime, be mixed together, they will so act upon each other as to restore the two pounds of chalk, which will, after the mixture, subside, leaving a bright water above. This water will be free from bicarbonate of lime, free from burnt lime, and free from chalk, except a very little, which we keep out of account at present for the sake of simplicity in this explanation. The following table will show what occurs when this mutual action takes place:—

AGENTS.			PRODUCTS.	
Bicarbonate of lime in 400 gallons	Chalk	16 oz.	= 16 oz. of chalk	= 2 lbs.
	with carbonic acid	7 oz.	= 16 oz. of chalk	
Burnt lime in 40 gallons of lime-water .		9 oz.		

"A small residuum of the chalk always remains not separated by the process. Of 17½ grains, for instance, contained in a gallon of water, only 16 grains would be deposited, and 1½ grains would remain. In other words, water with 17½ degrees of hardness arising from chalk, can be reduced to 1½ degrees, but not lower.

"These explanations will make it easy to comprehend the successive parts of the softening process.

"Supposing it was a moderate quantity of well-water from the chalk strata around the metropolis that we had to soften, say 400 gallons. This quantity, as has already been explained, would contain one pound of chalk, and would fill a vessel 4 feet square by 4 feet deep.

"We could take 9 ounces of burnt lime made from soft upper chalk; we first slack it into a hydrate by adding a little water. When this is done, we would put the slacked lime into the vessel where we intend to soften, then gradually add some of the water in order to form lime-water. For this purpose at least 40 gallons are necessary, but we may add water gradually till we have added thrice as much as this; afterwards we may add the water more freely taking care to mix intimately the water and the lime-water or lime. Or we might previously form saturated lime-water, which is very easy to form, and then make use of this lime-water instead of lime, putting in the lime-water first and adding the water to be softened. The proportion in this case would be one bulk of lime-water to ten bulks of the hard water.

"It is of importance that the lime, or lime-water, that is the softening ingredient, be put into the vessel first, and the hard water gradually added, because there is thus an excess of lime present up to the very close of the process, and this circumstance is found to render the precipitation of the carbonate of lime produced in the process more easy.

"But what you will wish to know now is, by what mark is the conductor of the process to find out when there is enough of water to take up the last of the excess of lime, so as to be enough, but no more.

"This is done by what has been called the silver test, the only test necessary to the operator after the process is fairly set a-going. This test is a solution of nitrate of silver, in twice-distilled water, in the proportion of an ounce per pint. In making use of the silver test with ordinary waters, we get a white precipitate; but if the water have in it a notable excess of lime-water, there is a light reddish-brown precipitate produced; but if the excess be very slight, we only get a feeble yellow precipitate. The way we make use of the test is to let two or three drops of it fall on the bottom of a white tea-cup; then add the water somewhat slowly; then if there be the slightest excess of lime, a yellow colour will show itself."

It may be here mentioned that a more delicate test than the silver test for ascertaining if there is an excess of lime in the water, consists in using a solution of cochineal, the natural colour of which is yellowish-red, which is turned violet in the presence of alkalies; and other agents are now used to show, by distinct colour, or its absence, if there is an excess or not of lime in the softened water.

According to Dr. Clark's scale, one degree of hardness means that there is one grain of chalk in a gallon of water. According to the scale introduced by Dr. Frankland, in the sixth report of the Rivers Pollution Commissioners, parts per 100,000 are used, or one grain of chalk in 100,000 grains of water, so that it is necessary, in considering the reports of the Rivers Pollution Commissioners, to bear in mind this difference of degrees of hardness. To reduce the hardness to parts per gallon, or to the Clark scale, it is necessary to multiply by 7 and divide by 10.

Hard water decomposes soap. The amount of soap ascertained by Dr. Clark to be wasted before softening the water, is equivalent to 2 ounces for each degree of hardness for every 100 gallons. Dr. Clark introduced a soap test, or a means by which a solution of soap is made to at once indicate the degree of hardness of a water. When pure chalk is burnt into lime, one pound is converted into 9 ounces of lime, and this quantity is soluble in 40 gallons of water. Beyond this, lime is not soluble in water, so that clear lime-water always possesses a known composition. This amount of lime is equivalent to 98·43 grains per gallon. As one particle of lime will remove $\frac{16}{9} = 1 \cdot 777$ of chalk, it follows that $98 \cdot 43 \times 1 \cdot 777 = 174 \cdot 9$, or the number of gallons of water one degree of hardness which one gallon of lime water will soften. In practice, however, while theoretically 175 gallons of water of one degree of hardness may be softened by one gallon of lime-water, owing to the impurities in the lime, probably not more than 130 to 150 gallons would be softened, so that, to arrive at the amount of lime-water necessary to soften hard water, if we divide 130 by the degrees of hardness according to Clark's scale, it will, generally, roundly represent the number of gallons of water which can be softened by one gallon of lime-water.

It is found in practice that neither by boiling nor by the time process can all the hardness which is termed "temporary hardness" be removed; in fact, a small quantity of chalk, to the extent of one part in 50,000 parts, is soluble in water, and still remains in solution after the process. In practice, however, 10–11ths of the whole of the temporary hardness may be removed by the lime process. In carrying out the Clark process, the lime-water is usually applied owing to the fact that it is a standard liquid containing a known quantity of lime, although cream of lime is sometimes used with advantage. Large tank space is required to carry out the Clark process, three tanks ordinarily being required, one for filling up, another for drawing down, and a third in reserve while cleansing is going on, and each tank should hold a day's supply.

It is a point of importance to know that the salts of iron may be readily removed by the application of lime. This the author found in the case of a water works at Horsham, where the water was so highly charged with iron, that everything it touched was discoloured ; but by the application of lime the whole of the iron was removed. It should also be noted that the process has a marked effect in removing organic matter from water. This was shown by the Rivers Pollution Commissioners and by the analysis published by Professor Wanklyn, especially in the marked diminution in the amount of albuminoid ammonia. The great objection raised against soft water has been its liability to produce lead poisoning ; but the consensus of opinion is that water softened by the Clark process is not liable to attack lead, which is a point of very considerable importance in favour of the process.

Dr. Clark's process was first carried out by the Woolwich and Plumstead Waterworks Company, where it was shown that the water was successfully softened from 23 degrees to 7 degrees. These works were subsequently bought by the Kent Waterworks Company, and the process of softening the water was discontinued. An experiment was also made at the Chelsea Waterworks Company's works, the result of which is set forth in the following Table :—

THAMES WATER AT THE CHELSEA WATERWORKS.

1851.		Degrees of Hardness.		REMARKS.
		Before liming.	After liming.	
February	24	14·0	4·5	The river was in good condition. The mixing was completed in 10 hours.
March	1	14·1	3·75	The river was in good condition. The mixing was completed in 9¾ hours.
,,	18	10·5	5·0	The river was in flood, and the flood tinge was retained after liming.
,,	22	11·6	4·8	Recovering from flood. The yellow flood tinge not removed.
April	17	15·5	3·6	The river in an average condition.

In the course of experiments made in softening various waters, it was observed that, if the water was at all tinted, the softening process did not clear it; but there was a tendency for the matters separated to remain in suspension in such water, so that it was considered expedient, in softening river-water, that the water should be filtered until quite bright before it undergoes the softening process.

It may be here mentioned that, in 1852, a patent was applied for (W. B. Bowditch) to treat water with clay and alkali, and subsequently filtering.

Mr. Phillip H. Holland, M.R.C.S., late Inspector to the Burial Act Office, suggested, as an addition to the Clark process, the use of oxalate of ammonia or soda, to further reduce the hardness of the water after treatment by this process. The use of carbonate of soda for softening water has been known throughout the whole country by tea-makers from an early period. This salt added to water acts on the bicarbonate of lime and magnesia, and precipitates chalk and carbonate of magnesia. It also decomposes the sulphates of lime and magnesia, precipitating the lime and magnesia, while the soda remains in solution, so that the permanent hardness of the water is reduced by the use of this salt. The Rivers Pollution Commissioners of 1874 state, in their sixth report, with reference to the use of carbonate of soda, that "the hardness of water is almost exclusively caused by the presence in solution of the bicarbonates and sulphates of lime and magnesia. These salts are all decomposed by carbonate of soda, slowly in the cold, but rapidly when the water is hot, insoluble carbonates of lime and magnesia being deposited or precipitated as a fine mud, while soluble bicarbonate and sulphate of soda are formed." The process, however, of using soda is much more expensive than the ordinary lime process, above 4¾ times as much soda being required to produce the same results as in the case of lime. An old receipt for softening water, and useful for some domestic purposes, is as follows :—Dissolve 6 lbs. of pearl-ash or sub-carbonate of soda in a gallon of soft water, boil the solution, and when boiling add 2 ozs. of soap, and stir until all the soap is dissolved. When this solution is added to water to be softened, the carbonate of soda and the soap combining with the salts producing both temporary and permanent hardness, form an insoluble compound by the combination with the soap, which coagulates and rises to the surface of the water, and may be skimmed off.

As any of the earthy alkaline earths may be used instead of, or in addition to, lime, it is not surprising that, since the date of Clark's patent, numerous patents have been taken out for softening and purifying water in which lime, in combination with other alkaline earths, have been proposed. For example :—

In 1849, Mr. John Horsley took out a patent for the use of calcined or caustic barytes, phosphate of soda, oxalic acid, or preparations of these substances.

In 1850, lime, in combination with chloride of barium, was patented.

In 1852, hydrate of potass and hydrate of soda, clay, and alkalies were the subject of separate patents.

In 1853 and 1854, hydrate of barytes, and hydrate of strontia formed the subject of patents.

In 1855, a patent was taken out for a powder containing oxalate of ammonia, peroxide of manganese, and charcoal.

In 1856, silicate of soda, in combination with carbonate of soda, was patented.

In 1856, bicarbonate of soda and oxalic acid, in crystals, were again proposed to be used.

In 1856 and 1857, carbonic acid was proposed to be introduced in conjunction with hydrate of lime.

In 1860, bicarbonate of soda and silicate of soda were again twice patented.

In 1862, the ordinary lime process was re-patented.

In 1863, the use of chloride of barium was patented.

In 1865, hypermanganate of potash, carbonate of soda, alum and neutralised aluminite, or a solution of iron was proposed ; and in another patent, sequi-sulphate of alumina was proposed as a means of purifying water. In another patent taken out in 1865 the use of soda and lime is again patented.

In 1866, a patent was taken out by a Mr. J. W. Tobin for an improvement on the Clark process for mixing the lime and filtering.

In 1866, the use of chlorine and permanganates, in combination with any alkaline earth, was patented.

In 1867, a patent was taken out for a preparation in a portable form, consisting of marsh mallow, linseed, bran, starch, gum, or any softening emollient, for the purpose of softening water for ablution purposes.

In 1868, the use of barytes was again patented, and the precipitate removed in vessels of a cellular form.

In 1869, the use of steam applied to water as a means of softening it was patented, the particles subsiding on shelves arranged in a vertical vessel.

In 1872, unslaked lime and sulphate of soda were patented as a means of purifying water.

In 1873, the lime process, in conjunction with a mixing and filtering arrangement, was patented ; also lime, carbonate of soda, chloride of barium, or other reagent in conjunction with filtering.

In 1874, the treating of water with lime and carbonate of soda in combination with filtration was proposed.

In 1875, the lime process pure and simple, and in combination with other reagents and filtering, was patented.

In 1876, the lime process in combination with filter presses was first patented by Mr. Porter.

In 1877, the use of oxide of magnesia and basic carbonate of magnesia was proposed ; also the use of a carbonate of potassa, silicate of soda, and nitre cake, used separately or combined.

In 1878, a patent was taken out for combining bicarbonate of soda with the lime process, and filtering upon the Porter-Clark plan.

In 1879, Mr. Porter took out an additional patent for carrying out automatically the softening and purifying of water. In the same year phosphoric acid and phosphate of lime were proposed as a means of softening water.

In 1880, the means of automatically carrying out the softening process, and adjusting the quantities by means of an arrangement of ball valves in a cistern, was patented.

In 1881, Mr. Porter took out a further patent for the automatic regulation of the supply of the solution of lime.

In 1881, Mr. Atkins took out a patent for treating water with lime, and subsequently filtering through a specially constructed filter.

In 1882, an apparatus for softening and clarifying water was proposed, in which sloping shelves in a vertical vessel were used, the water entering the bottom of the vessel and flowing off at the top ; or concentric cylinders overflowing from one to another might also be used with the same object.

In 1883, Messrs. Gaillet and Huet's apparatus for softening water was patented, consisting of sloping and V-shaped shelves in a vertical vessel, the water entering at the bottom and flowing out at the top.

The use of steam and caustic soda was also patented.

A patent was also taken out for the use of phosphate of soda, and an apparatus for measuring the water and lime to be used in the softening process.

Modern Inventions for Softening Water.—The modern inventions for carrying out the Clark process may be described as the application of machinery to the saving of time, space, and labour. Of those in general use, dealing with them in the order of date, the Porter-Clark process comes first. In the ordinary Clark process, lime-water, in known quantity, is first admitted into a tank, to which the water to be softened is added. However, in some cases the lime-water and the hard water are allowed to flow in together into the tank, but it was considered by Dr. Clark to be an advantage, in carrying out his process, for the hard water to be brought into contact with an excess of lime-water in the first instance, which was let into the tank before the water to be softened was added. In the ordinary Clark process, not less than sixteen hours were required for the softening and subsidence of the matters separated from the softened water. In the Porter-Clark process, instead of allowing the particles of carbonate of lime to separate and subside, a brisk agitation is maintained, so that these particles remain in suspension to permit chemical reaction with the lime, and the purification of the hard water, which, when completed, is passed onward to filter presses, where the carbonate of lime adheres to the filtering cloth. The subsequent operations of filtering through the deposit on the cloth then takes place, and the water is passed away at once in fit state for use, so that the process is continuous in its action, and may be carried on just as quickly as water can be pumped from a well, provided the apparatus is of sufficient capacity to allow time for the water to remain in contact with the lime in passing through the machine. The lime in this case is passed through horizontal cylinders, which are termed lime-churns, and is constantly churned up with water, and the lime-water so made is, by suitable arrangements, allowed to mix with the ordinary water in proper proportions, after which it is again agitated. Mr.

Porter has also an apparatus by which, instead of using ordinary filter presses, he can use filter frames, and where power is not available, he also suggests a means of working the process without such power. In some cases the power obtained from the pressure of the water is utilised for working the apparatus. An apparatus of this description may be seen at the Camden Town locomotive sheds of the London and North Western Railway, and the apparatus may also be seen at work within this Exhibition.

The Atkins Process is also a modification of the Clark process, by which the space formerly required is reduced. The lime is put into a vessel where lime-water is formed, and this water is allowed to mix in its proper proportion with the water to be softened in a specially arranged mixing vessel, after which it passes into a reservoir of small dimensions. From this reservoir it is conveyed to filtering vessels which contain a special arrangement of filter, consisting of a series of chambers mounted upon a central hollow shaft, these disc chambers being covered with prepared canvas, upon which the deposit of chalk, &c., adheres, and through which the softened water filters. The filters are cleansed by means of revolving brushes. The apparatus does not require power to maintain it while at work, the only power used being that necessary to give motion to the brushes when the apparatus is cleansed. The system may be seen at work at the Henley-on-Thames Waterworks, and at other places.

In the Process of M. Maignen, a powder is used which the inventor calls "Anti-calcaire." This powder is made of variable composition in order to suit the special characteristics of the water to be treated, the ingredients used for ordinary hard water being lime, soda, and alum in suitable proportions. In the apparatus, which is at work at the International Health Exhibition for softening water for some of the breeding tanks, the water entering the apparatus gives motion to a water-wheel, which in its turn works an arrangement for distributing a given quantity of the softening agent, and causing it to pass into the water.

The water is then allowed to subside in a small tank, and is eventually filtered through filters covered with asbestos cloth, the basis of the filter being similar to that of the "Filtre Rapide." A part of the carbonate of lime and magnesia deposited from the water adheres to the filtering surface, and the softened water filters through it. The apparatus may be seen at work in this Exhibition.

The Process of Messrs. Gaillet and Huet.—In this process, which was patented in February, 1883, the patentees make use of certain known agents, the patent itself applying to the apparatus used for the purpose of producing the results after the chemicals have been applied. The agents they propose are lime and caustic soda. Whenever the water contains organic matter, they use salt of alumina or iron in addition. Iron, however, is not recommended in any case where the water is required for washing purposes. The apparatus consists, virtually, of a series of tanks in duplicate, in which the chemicals are mixed, and these enter a vertical pipe in proper proportion to the water to be softened, and which communicates with the bottom of an upright chamber divided by a series of sloping shelves, through which the water gradually works upwards in a zig-zag path. These shelves slope in one direction, and are of V shape, so that as the deposit takes place it accumulates at one point, at which there is an opening ordinarily closed by a tap, and when any tap is open the deposit on the sloping shelf communicating with it is washed out. The apparatus appears to be extremely simple in its design, but its efficiency has yet to be tested, although it is at work at Messrs. Duncan's, Victoria Docks, where the water is reduced from 24 degrees to 6 degrees and the Thames water is reduced from 16 degrees to 2 degrees.

Purification by Distilling.—It is not necessary to devote any large amount of attention to the question of purifying water by the process of distillation. The process is one which has been used from remote periods in order to produce absolutely pure water, and during the last forty years very great improvements have been adopted in order to bring this process into more general application in connection with the purposes of water supply. The difficulty of obtaining absolutely pure water is practically exemplified by this process, for in attaining this result, unless the water is distilled some two or three times, and every time a large proportion of the residue is discarded, pure water cannot be obtained. In the case, however, of water distilled for dietetic purposes, it is not necessary to carry out the process to the extent required in procuring water for some chemical purposes. It has generally been considered that distilled water lacks aëration, and on this account it has been strongly recommended that it should be filtered. The great improvements in the process of distillation are due to Dr. Normandy, whose first patent, taken out in 1851, has been improved upon by many subsequent patents. The process has been adopted with the greatest possible advantage in many of our ocean steamers, and the preservation of the health of the crews and passengers visiting countries liable to the ravages of epidemic disease is, in a great measure, due to the use of this process. It is generally believed by many high sanitary authorities that if this system were adopted at malarious stations, one of the largest channels by which infection is disseminated would be effectually closed. Dr. Macnamara states that on our ocean steamers, "as a general rule, condensed sea-water is employed for drinking purposes, which, although it may not be always very palatable, must obviously be free from all chance of choleraic contamination;" and this is one of the great safeguards to Europe against the spread of cholera.

Softening by Exposure.—The exposure to the air of water containing salts which are held in solution by carbonic acid causes a loss of carbonic acid. Water of deep wells which has been in contact with chalk and other rocks often contains free carbonic acid by exposure, especially under the inequalities of diurnal temperature, the original charge of ground air is got rid of, and pure atmospheric air takes its place. On exposure to air, hard waters are especially liable to develop vegetable growth. A few days' exposure of very hard water in the summer time will soon develop green confervoid growth, and so soon as this growth takes place, carbonic acid is rapidly used up by it, so that the bicarbonates in the water are soon converted into simple carbonates, and are precipitated. Water, therefore, exposed to air undergoes a chemical metamorphosis; the bicarbonates of lime and magnesia are converted into carbonates, and are precipitated, and it is in this way that exposure assists in softening water.

Softening by Freezing.—Pliny, speaking of the quality of water and of the controversy going on in his time amongst physicians as to the use of water, says that some people preferred rain-water above all others, because it is the lightest. He also says that some prefer "snow-water before that which cometh down in showers; and the water of ice dissolved before the other of melted snow," and he goes on to say that the rain, snow, and ice are all lighter than those which spring out of the earth, and ice amongst the rest far lighter than any water in proportion. Ice taken from hard or other impure waters, if found to be perfectly crystalline and free from air bubbles, will produce, on melting, a water as soft as that of distilled water. If, however, the ice contains air bubbles or cavities of any description, such water will not be entirely pure. Some years ago the author made an extensive series of experiments upon the degree of purity which might be arrived at by freezing water, when it was shown that the act of freezing may be carried to such an extent as to produce, in the remaining water, a precipitation of the salts in solution; but ice frozen upon very superficial water was found liable to have the impurities frozen in it which adhered to the under sides of the ice, and which became embedded in it by subsequent freezing; but water which has been largely deprived of air by boiling or exposure, upon being frozen, if perfectly crystalline, will produce absolutely pure water. Several patents have been taken out with a view to freezing sea-water so as to furnish a supply of fresh water on board ship, but such processes will not compete, from an economical point of view, with the process of distillation.

Geological.—The geological formations which furnish water of a quality suitable to be softened are those of the dolomitic or magnesian limestone, which gives great hardness to water, for while salts of lime render water hard and troublesome, in washing, those of magnesia cause the water to curdle, and render it considerably more disagreeable for washing and ablution. The mountain limestone, which is ordinarily of an impermeable nature, does not yield water of such a hard quality as those of the magnesian limestone. The waters of the oolite and chalk are chiefly hard from what has been termed temporary hardness, that is due to the presence of bicarbonates of lime and magnesia in the water, which may be got rid of by boiling, or by the lime process. The waters of the new red sandstone and Permean beds vary considerably in hardness ; many of them have a considerable permanent degree of hardness, but there are none of them which may not be softened to a great extent by the adoption of the lime process, while this process, in combination with the other alkaline earths, such as soda, when the water is not intended to be used for dietetic and washing purposes, will still further reduce the hardness of these waters.

The surface wells of the country, usually sunk in drift covering various geological formations, furnish water of various degrees of hardness. Scarcely any such wells yield a soft water, and in most instances, when these wells are sunk in populous places, in addition to their natural hardness, the waters are highly polluted, and such waters ought never to be used for dietetic purposes, unless they are first boiled.

ON THE DETECTION OF SEWAGE CONTAMINATION BY THE USE OF THE MICROSCOPE, AND ON THE PURIFYING ACTION OF MINUTE ANIMALS AND PLANTS.

By H. C. Sorby, LL.D., F.R.S.

By studying with the microscope the solid matters deposited from the water of a river, the previous contamination with sewage can usually be detected without any considerable difficulty. If the amount be serious, the characteristic particles of human excrement can easily be seen ; and even if it is small, and has been carried a long way by the current, it can usually be recognised by means of the hairs of oats derived mainly from the droppings of horses, which resist decomposition for a long time, and are not consumed as food by minute animals. I, however, do not propose to enter into detail in connection with this part of my subject, but specially desire to call attention to the connection between the number of minute animals and plants, and the character of the water in which they live, and also to their influence in removing organic impurities.

For some time past I have been carefully ascertaining the number per gallon of different samples of river and sea-water, of the various small animals which are large enough not to pass through a sieve, the meshes of which are about $\frac{1}{200}$th part of an inch in diameter. The amount of water used varies from ten gallons downwards, according to the number present. By the arrangements used there is no important difficulty in carrying out the whole method in a satisfactory manner. I confine my remarks entirely to general mean results.

The chief animals met with in fresh water are various entomostraca, rotifera, and the worm-like larvæ of insects.

I find that the number per gallon and percentage relationships of these mark, in a most clear manner, changed conditions in the water, the discharge of a certain amount of sewage being indicated by an increase in the total number per gallon, or by an alteration in the relative numbers of the different kinds, or by both. All my remarks apply to the warm part of the year, and not to winter.

It is known that entomostraca will eat dead animal matter, though probably not entirely dependent on it. I have myself proved that they may be kept alive for many months by feeding them on human excrement, though they soon died without it. If the amount of food in any water is small, not many of such animals can obtain sufficient; but if it be abundant, they may multiply rapidly, since it is asserted that in one season a single female cyclops may give rise to no less than four thousand millions of young. In stagnant muddy ponds, where food abounds, I have found an average of 200 per gallon. In the case of fairly pure rivers the total number of free-swimming animals is not more than one per gallon. I, however, found that where what may be called sewage was discharged into such water the number per gallon rose to 27, and the percentage relationships between the different groups of entomostraca were greatly changed. In the Thames at Crossness, at low water, the number was about six per gallon, which fell to three or four at Erith, and was reduced to less than one at Greenhithe.

There is, however, a very decided limit to the increase of entomostraca when the water of a river is rendered very impure by the discharge of too much sewage, probably because oxygen is deficient, and free sulphide of hydrogen present. Such water is often characterised by the great number of worm-like larvæ of insects. Thus, in the Don, below Sheffield, in summer, I found the number per gallon, of entomostraca, only about one-third of what it is in pure waters; whilst, on the contrary, the number of worm-like larvæ was more than one per gallon.

Now if the minute free-swimming animals thus increase when a certain amount of sewage supplies them with ample food, it is quite obvious that they must have a most important influence in removing objectionable impurities. The number of the excrements of entomostraca in the recent mud of such rivers as the Thames is most surprising. In one specimen, from Hammersmith, I found that there were more than 20,000 per grain; and the average number at Erith, in August, 1882, was above 7000, which is equivalent to about 200,000 per gallon of water at half-ebb, from the surface to the bottom. This enormous number must represent a very large amount of sewage material consumed as food; and though, as in the case of larger animals, a considerable part of their excrements no doubt consists of organic matter capable of putrefaction, yet there can be no less doubt that the amount entirely consumed in the life processes of the animals is also great.

As named above, I kept cyclops alive for many months by feeding them on human excrement. It is thus easy to understand why, when they abound in the Thames, the relative amount of human excrement is very considerably less than in the winter, when their number must be much smaller.

We thus appear to be led to the conclusion that when the amount of sewage discharged into a river is not too great, it furnishes food for a vast number of animals, which perform a most important part in removing it. On the contrary, if the discharge be too great, it may be injurious to them, and this process of purification may cease. Possibly this explains why in certain cases a river which is usually unobjectionable may occasionally become offensive. It also seems to make it clear that the discharge of rather too much sewage may produce relatively very great and objectionable results.

Though such comparatively large animals as entomostraca may remove much putrefiable matter from a river, we cannot suppose that, except incidentally, they remove such very minute objects as disease germs, but it would be a subject well worthy of investigation to ascertain whether the more minute infusoria can, and do, consume such germs as a portion of their food. If so, we should be able to understand how living bodies, which could resist any purely chemical action likely to be met with in a river, could be destroyed by the digestive process of minute animals. Hitherto I have had no opportunity for examining this question critically, but have been able to learn certain facts which, at all events, show that it is well worthy of further examination. It is only during the last month that I have paid special attention to the number of the larger infusoria, and various other animals of similar type, met with per gallon in the water of rivers and the sea, which can be seen and counted by means of a low magnifying power. At low water in the Medway above Chatham, in the first half of June, the average number per gallon has been about 7000, but sometimes as many as 16,000. Their average size was about $\frac{1}{1000}$th of an inch. Possibly the number of still more minute forms may be equally great; but, even if we confine our attention to those observed, we cannot but conclude that their effect in removing organic matter must be very considerable; and judging from what occurs in the case of larger animals, those $\frac{1}{1000}$th of an inch in diameter may well be supposed to consume as food, particles of the size of germs. Up to the present time, I have however collected so few facts bearing on this question, that it must be regarded merely as a suggestion for future inquiry.

So far, I have referred exclusively to the effect of animal life. Minute plants play an important part in another way. The number per gallon of suspended diatoms, desmids, and confervoid algæ is, in some cases, most astonishing, and they must often produce much more effect than the larger plants. As far as I have been able to ascertain, their number is, to some extent, related to the amount of material in the water suitable for their assimilation and growth. In the mud deposited from pure rivers their number is relatively small, but in the district of the

Thames, where the sewage is discharged, I found that in summer their number per grain of mud at half-ebb tide was about 400,000, which is equivalent to above 5,000,000 per gallon of water. This is two or three times as many as higher up or lower down the river, and, out of all proportion, more than in the case of fairly pure rivers like the Medway. Their effect in oxygenating the water must be very important, since, when exposed to the light, they would decompose carbonic acid, and give off oxygen, under circumstances most favourable for supplying the needs of animal life, and counteracting the putrefactive decomposition so soon set up by minute fungi when oxygen is absent.

Taking, then, all the above facts into consideration, it appears to me that the removal of impurities from rivers is more a biological than a chemical question ; and that in all discussions of the subject, it is most important to consider the action of minute animals and plants, which may be looked upon as being indirectly most powerful chemical reagents.

ON THE CHEMISTRY OF POTABLE WATER.

By Professor Odling, M.B., F.R.S., F.R.C.P.

President of the Institute of Chemistry.

I.—Sources of Water Supply.

The water of most towns is derived, as is well known, from one or other of three typical sources, constituted respectively by springs, or streams, or lakes, this last named source being taken to include not only natural lakes, but also those huge artificially formed reservoirs, in which the surface water collected from more or less extensive gathering grounds, is retained by means of embankments, and stored up for distribution to consumers. Although some streams, indeed, are fed largely by springs, and some lakes are little else than local expansions of streams or rivers, still a general distinction in character between supplies derived from the three just spoken of typical sources, is, on the whole, broadly recognisable ; and this, notwithstanding the fact of the considerable differences in com position manifested by individual spring-waters, derived from different springs or wells, by individual stream-waters, derived from different streams or rivers, and by individual lake-waters, derived from different lakes or reservoirs. Despite the marked preference of a few authorities for some one variety of source to the exclusion of the others, the majority of engineers have come to recognise each variety as having its own characteristic excellencies and concomitant defects, and are accordingly ready to avail themselves, in different cases, of whatever kind of source is rendered by local circumstances most available and suitable for the particular town to be supplied. From all three varieties of source alike, numerous large populations have been furnished for generations past, with an abundant, and, as the result has shown, with a satisfactory and wholesome supply of water ; although, indeed, in a few special instances, supplies from all three varieties of sources alike have, in different ways and under exceptional circumstances, proved detrimental to the health, and even, in certain cases, fatal to the lives of some among the population supplied. All three varieties of source have, under the best advice of the time, been continually resorted to from the earliest period of water supply undertakings, nearly three centuries ago, down to the present day. Thus, while the youngest of the companies supplying London has obtained its supply, since 1862, wholly from deep wells sunk in the chalk, the new works for the supply of Liverpool and Manchester respectively, which may both take rank among the greatest hydraulic undertakings of the century, are intended to introduce and distribute river-water in the one town and lake-water in the other. All experience, indeed, goes to show that the supply of excellent water is not confined to its supply from any single variety of source; and that for the purpose of water supply, there are alike good wells and bad wells, good lakes and bad lakes, good rivers and bad rivers. Just, moreover, as the best of river-waters or lake-waters will fall short in regard to an excellency characteristic of well-water, so will the best of well-waters fall short in regard to an excellency characteristic of lake-water or river-water. The comparison of the one sort with the other sorts of water must be made as a whole. To select arbitrarily the special good point of one sort of water as a standard, to the neglect of the countervailing good points of other sorts, and to measure the quality of the other sorts solely in reference to this selected standard, is clearly the conduct rather of an advocate than of a judge.

2.—PURITY OF WATER.

Water, as conceived of by the chemist, is a definite conpound of 100 parts by weight of oxygen, united with 12·5 parts by weight of hydrogen. So exceedingly difficult is it of production, even if it ever has been produced in an absolutely pure state, that it may be regarded rather as an ideal than a real chemical substance. All natural water, besides the matter, never entirely absent, which it holds in suspension, is a solution of various mineral matters, of various organic matters, and of various gases in the ideal water, or protoxide of hydrogen, of the chemist. Of the different kinds of foreign substance habitually or exceptionally present in natural water, some kinds are beyond question prejudicial, and in particular cases highly prejudicial; most kinds are simply innocuous; while not a few kinds, as saline matter in moderate proportion, and more particularly dissolved aerial matter, are positively beneficial. Looked at, however, from a strictly chemical point of view, any matter whatever foreign to the ideal chemical compound, water, constitutes an impurity of the natural water in which it occurs, whether this foreign matter be a prejudicial or a beneficial constituent, whether it consist of sewage matter, by which the water is fouled, or of healthful oxygen, by which it is aerated. The chemist uses the word pure, not in the sense of opposite to nasty, but much in the way it is often used in ordinary language, to express the exclusion from one thing of anything else, whether better or worse. Thus, we talk no less familiarly of pure rubbish or pure dross than of pure gold. We speak of pure nonsense as readily as we speak of pure truth, irrespective of the circumstances that the nonsense would be benefited, though to the prejudice of its purity, by its contamination with a few grains of sense. So chemists speak of pure water, irrespective of the circumstance that, for all the needs of life, the water is benefited, though to the prejudice of its chemical purity, by the presence of its dissolved gases, and of a proportion of dissolved saline matter. Chemists, then, are in the habit of using the word "purity" to signify oneness of chemical nature. Accordingly, in the eyes of a chemist, the matter, for example, of an old copper penny would have its degree of purity equally lowered by the same addition made to it of any kind of other matter, whether of base metal, like tin, or of noble metal, like silver, or even gold. Similarly, in the case of natural water, the small proportions of other substance existing together with the main substance, protoxide of hydrogen, interfere with the oneness of its chemical nature; or, in other words, constitute the natural water a mixture of substances, instead of being a single substance, which is alone looked upon by the chemist as a pure substance. It follows, that the water of the chemist is one thing, the water of nature another. The ideal water of the chemist is a single substance; the water of nature, like the air of nature, is a mixture of substances. Just as this last is a variable mixture of the pure chemical substances —nitrogen, oxygen, water vapour, carbonic acid and ammonia, with traces of various other kinds of matter, so is the water of nature a variable mixture of the pure chemical substances—protoxide of hydrogen, common salt, saltpetre, gypsum, limestone, carbonic acid, nitrogen, and oxygen, &c., together with various kinds of organic matter.

Air, from which the minor constituents of atmospheric air have been carefully abstracted, is sometimes spoken of as purified air ; but air, deprived in this way of its so-called impurities, is absolutely incapable, in relation alike to animal and vegetable life, of fulfilling the functions of an atmosphere. The substitution of such purified air for actual atmospheric air would mean the cessation on the earth's surface of all life as it now exists. Similarly, with regard to natural water, some of its minor constituents we know to be essential, others of them we have reason to think advantageous to the fulfilment of its functions in nature. Bearing in mind, indeed, the interaction everywhere of life and the conditions of living, we can scarcely doubt that the actual mixed substance, water, is better suited to supply the wants of our daily life, than the ideal unmixed substance would be ; and further, we have no reason whatever to look upon this ideal substance as furnishing a standard of excellence, to which it is desirable that our daily supply should, as far as practicable, and in all respects, approximate. What we really desiderate is not chemical purity, but hygienic freedom from anything hurtful. In some water, as in some air, an objectionable constituent may be met with ; but in the case neither of water nor air, is there any presumption on the score of wholesomeness, in favour of a single substance as such, rather than of a mixed substance as such. The presumption is indeed the other way. No one desires unmixed oxygen, or even oxygen and nitrogen free from commixture with the minor constituents of our native air ; so neither is there any reason to desire unmixed protoxide of hydrogen, freed from the minor constituents of wholesome natural water. It is clearly open to a chemist, addressing himself to chemists, to speak of the constituents of ordinary water, other than protoxide of hydrogen, as impurities in the water ; provided of course that he is consistent, and includes the desirable dissolved gases of the water among its impurities and as contributories to the sum total of its impurity. It is also open to a chemist, addressing himself to chemists, to make a comparison of different natural waters, in respect to the relative proportions of their total impurity, or of their saline impurity, or of their calcareous impurity, or of their organic impurity, or of their aerial impurity, &c. But it is not, I take it, open to a chemist addressing the general public, to speak as a chemist of some particular selected constituent, characteristic of the class of natural waters derived from one kind of source, as an impurity, and to leave it to be inferred by the general public that because this constituent is, in a strict chemical sense, an impurity, it is therefore a something nasty and unwholesome, and that the class of waters in which it is more especially met with are, in proportion to the extent of its presence, nasty and unwholesome. The general public do not know that the chemical impurity of a water may be good or bad, noxious or innoxious, desirable or undesirable, wholesome or unwholesome. They are unaware that no scale of wholesomeness or desirableness can be inferred from a scale of chemical purity, with respect to some particular constituent stigmatised as an impurity, until it has been established by evidence that this particular chemical impurity is of an unwholesome or prejudicial character. It is a mere dialectic artifice, and not a very worthy artifice, to use the word impurity in a strictly scientific sense, with intention to have it accepted in a popular sense as bearing a meaning which, scientifically, by no means belongs to it.

3.—ORGANIC MATTER OF WATER.

The saline matter of water is a useful expression to denote the sum of the dissolved mineral constituents, and the organic matter of water a useful expression to denote the sum of the dissolved organic constituents of natural water. The saline matter of one water is not necessarily, or yet commonly, identical with the saline matter of another water; nor is the saline matter of the selfsame body of water necessarily identical throughout its entire extent, or from one period of time to another. The same holds good with regard to the organic matter of water. It is a different thing in one water from what it is in another; and may be different in the same water from place to place and from time to time. But just as there is a character or nature more or less common to the usual varieties of dissolved saline matter, so also is there a character or nature common, within certain limits, to the usual varieties of organic matter met with in potable water. So far a certain parallelism holds good between the saline matter of water on the one hand, and its dissolved organic matter on the other. But in many important particulars the parallelism fails. Thus the saline matter occurs, for the most part, in appreciable proportion, say from $\frac{1}{100}$ to $\frac{1}{20}$ of a per cent. It is constituted of definite chemical substances, possessed of well-determined properties; and its amount is capable of estimation with all desirable accuracy—with considerable accuracy by direct weighing, and with yet greater accuracy indirectly, by the separate estimation of its several constituents. The dissolved organic matter of potable water on the other hand, never amounts to more than an exceedingly minute proportion, say from $\frac{1}{5000}$ to $\frac{1}{1000}$ of a per cent.; what are its separate constituents, and what their chemical nature, is almost, if not wholly, unknown; its amount is moreover incapable of direct determination, and the different means for its indirect determination are far from satisfactory. Chemists are capable, however, thanks to Dr. Frankland, of determining with a considerable degree of accuracy, the quantity of carbon that exists in any water, in the form of organic matter. Evidently, if all organic matter contained the same proportion of carbon, a determination of the organic carbon present in any water would be tantamount to a determination of its organic matter. But in reality the proportion of carbon existing in different individual varieties of organic matter has, on the contrary, a very wide range of variation. Still, it would appear, from such imperfect investigations as have been made, that the proportion of carbon existing in the organic matter of water—that is to say, the mean proportion of carbon present in the whole of the several individual constituents of the organic matter, taken together—is not subject to any such considerable range of variation, and that it may, without risk of serious error, be valued at about 40 per cent. Disregarding then for the moment the consideration of the nature of the dissolved organic matter present in natural water, and confining attention only to its quantity, it may be taken as admitted that the determination of the organic carbon in water is an absolute, and more than fairly accurate determination; that the organic matter of water is in a general way proportionate to the amount of its organic carbon; that the amount of organic matter may accordingly be represented by some multiple of the organic carbon; and that for purposes of comparison, at any rate, this multiple may be taken provisionally at 2·5, corresponding, of course, to the occurrence of 40 per cent. of carbon in the organic matter.

The inquiry next presents itself as to what, on the basis of these propositions, is the quantity of organic carbon, and consequently of organic matter present in the three classes of water derived respectively from each of our typical varieties of source. Speaking generally, it may be said that the proportion of organic matter is decidedly least in spring or well-water—that is to say, if we limit our attention to such waters only as would be taken for town supply, for there are, of course, foul well-waters, in which the amount of organic matter is in excess of anything ordinarily met with in the water of lakes and natural rivers. As between lake sources in general, and river sources in general, it is not easy to assign the order of seriation. The proportion of organic matter found in different lake-waters is, on the whole, more uniform than the proportion found in the waters of different rivers. Accordingly, while in some river-waters the proportion of organic matter is somewhat higher, there are other river-waters in which it is very considerably lower than the proportion commonly present in lake-water. On the whole, it would seem that river-water in general must take precedence of lake-water in respect to the smallness of its proportion of dissolved organic matter, subject, however, to the observation that the proportion of this constituent is more variable in river-water—that it is liable to a greater range of variation, both as between the water of one river, and the water of another, and as between the water of the same river at different seasons. In order to give some idea of the quantities of organic carbon, and consequently of organic matter, present in the water, furnished from different varieties of source for town supply, I have made an abstract of the results set forth in the Registrar-General's monthly reports for the last year and a half, beginning, that is to say, with the report for January, 1883, and ending with the report last made, for June, 1884, in respect to the supplies of London, Birmingham, and Glasgow. I have resorted to the reports of the Registrar-General in part, because they alone furnish the results of a regular series of analyses of the water supplied to other towns than London; and, in part, because, with regard to London, I have, for the purpose of this address, preferred to bring before you the results of analyses for which I am not in any way responsible. There is not, however, any appreciable difference between the mean results for the period obtained by Dr. Frankland, on the one hand, and by my colleagues and myself on the other, in respect to the composition of the London waters examined by both of us.

The five Thames waterworks companies, as is well known, take their supply from the river at Hampton, Ditton, and Molesey. They furnish just under 50 per cent. of the total supply of the metropolis. The East London Waterworks Company take their supply from the River Lee, some distance below Ware. Their subsiding reservoir at Walthamstow has the enormous area of 222 acres, equal to that of a good-sized lake. The company have power to take in addition ten million gallons of water daily from the Thames at Sudbury. It is but seldom, however, that they resort to the Thames at all; and very rarely indeed to the extent of more than one quarter of the daily amount they are privileged to obtain. Substantially, the water of the East London Company is water from the Lee. The New River Company take somewhere about four-fifths of their supply from the Lee, above Ware, and the remaining one-fifth from Chadwell springs and a series of deep wells sunk in the chalk. The East London and New River Companies, jointly, furnish about 44 per cent. of the total supply of the metropolis. The Kent Waterworks Company take their water entirely from deep wells in the chalk, and furnish from this source rather more than 6 per cent. of the total supply of the metropolis. The water supplied to the town of Birmingham by the Corporation is taken from various sources, lake or reservoir, stream and well, but in what relative proportions I am unable to say. The water supplied to the town of Glasgow by the Corporation is taken, as is well known, from Loch Katrine. The underneath table shows the actual quantities of organic carbon, expressed both in parts per 100,000 and in grains per gallon, and the estimated quantities of organic matter in grains per gallon, present in these six several supplies of water, as determined by monthly analyses of the waters conducted during the last year and a half.

MEANS OF EIGHTEEN MONTHLY ANALYSES, 1883–84.

Source.	Proprietary.	Organic Carbon.		Organic Matter
		Parts per 100,000.	Grains per gallon.	Grains per gallon (estimated).
Chalk Springs . . .	Kent Company . . .	·047	·033	0·083
River Lee and Springs .	New River Company .	·089	·062	0·156
Mixed	Birmingham Corporation	·132	·093	0·231
River Lee	East London Company .	·139	·098	0·245
Loch Katrine . . .	Glasgow Corporation .	·147	·103	0·257
River Thames . . .	The Five Companies. .	·164	·115	0·286

It will be seen that the organic matter of the Kent Company's water, which is a spring-water, is under one-tenth of a grain per gallon; that the organic matter of the New River Company's water, which is mainly a river-water, is considerably under two-tenths of a grain per gallon; that the organic matter of the East London Company's water, which is a river-water, that of the Birmingham Corporation's water, which is a mixed water, and that of the Glasgow Corporation's water, which is a lake-water, are alike about two and a-half tenths, *i.e.*, a quarter, of a grain per gallon; while the organic matter of the Thames Companies' supply of river-water is under three-tenths of a grain per gallon. It is to be noted, however, that, although the average proportion of organic matter in the Thames-derived water supplied to London, is a little in excess of that in the Birmingham and Glasgow Corporations' supplies, the excess is entirely due to the effect of the winter floods. Comparing the results in the summer nine months, March to September, 1883, and March to June, 1884, the proportion of organic matter in the Glasgow Corporation's supply is somewhat in excess of the proportion found in the Thames supply, the number of grains of organic matter, being for the Thames derived water ·22 and for the Glasgow water ·25 grain per gallon. Similarly, the organic matter of the East London Company's water, during the summer months, falls appreciably below that of the Glasgow Corporation's supply at the same season of the year,—the season, that is to say, during which a high character of water is considered to be more especially demanded. The above statements, as to the particular fractions of a grain of organic matter ordinarily present in a gallon of different kinds of water, serve to convey some idea of the always exceeding smallness of the quantity. A better notion, however, of the minuteness of even the highest proportions of organic matter found, say, in any London water, is afforded by stating the results in another way. Thus, if we suppose for an instant that the Thames companies' water, instead of containing under three-tenths of a grain, contained seven-tenths of a grain of organic matter per gallon—a maximum which has been occasionally approached in the supply of one or other of the Thames companies at a period of flood—even this exceptional proportion would but correspond to the presence in the water of exactly the thousandth part of one per cent. of organic water. Whether or not, variations within the limit of such a small proportion of dissolved organic matter present in potable water, ranging from about the one-thousandth part of one per cent. exceptionally met with in a Thames-derived water, down to the eight-thousandth part of one per cent. habitually met with in a chalk-spring water, are matters of any real significance, must obviously depend on the character of the dissolved organic matter present in the different waters. It will suffice for the present to observe that, so far as mere quantity of organic matter is concerned, the water supplied to London from the Thames and Lee takes, on the whole, precedence of the highly reputed, and deservedly reputed, water furnished to Glasgow; as, doubtless, it will take precedence of the water about to be furnished to Manchester.

As regards range of variation, it is noticeable that, while the mean proportion of organic matter present in the summer supply of the Thames Companies, as calculated from the average of forty-five analyses reported to the Registrar-General, is ·22 grain per gallon; and the mean proportion present in the yearly supply, as calculated from the average of ninety analyses, is ·28 grain per gallon; the proportion in one particular sample of water out of the ninety samples analysed, fell to ·17 grain, in two samples it rose to ·50 grain, in one sample to ·53 grain, and in yet another sample to ·60 grain; but that in no one sample out of the ninety did it reach the maximum of ·70 grain per gallon, so as to constitute the thousandth part of 1 per cent. of the water. It happens similarly in nearly all natural waters, that while the absolute variation in the proportion of organic matter present at different times is almost infinitesimally small, the relative variation is, on the other hand, strikingly large. Thus, the proportion of organic matter present in the Glasgow Corporation's lake-water at different times varies as 1 to 2; that in the Kent Company's spring water, in the East London Company's water, and in the Thames Companies' water, varies as 1 to 3 or 3½; that in the New River Company's water varies as 1 to 4; and that in the Birmingham Corporation's water varies as 1 to 7; but the larger range of variation in the water of these last two supplies is dependent, doubtless, on the circumstance of their being mixed supplies, constituted of unequal proportions of their several contributories at different times. In the official phraseology with which we are so familiar—phraseology of but little meaning, though the words are strong—it would be said that while the degree of "pollution by organic impurity" of the Glasgow water is twice as great at one time as at another, the degree of "pollution by organic impurity" of the Birmingham water is seven times as great at one time as at another. The large extent of relative variation thus noticeable in respect to the organic matter of water, is common, as might be expected, to those other of its constituents, which also exist absolutely in very small quantity, and is, indeed, almost a consequence of the smallness of their absolute quantity. A somewhat parallel comparison may be adduced in the case of personal wealth. We know that while the wealth of a capitalist will, for the most part, vary only by a small percentage from month to month, the whole fortune of a beggar, his utmost riches being a matter of no consideration, may vary manyfold in the course of a day, although by the absolute amount of only a few halfpence put into or taken out of his ragged pocket.

4.—GENERAL CONSIDERATIONS.

So far, attention has been directed to the organic matter of potable water, solely from the point of view of its quantity. A much more important inquiry, however, has reference to its nature or quality. But this is too large and important a matter to be taken up at the fag end of an address, limited strictly to the duration of a short half-hour. That the organic matter of potable water is constituted, in the main, of dissolved, unorganised, and non-living matter, does not admit of question. Anything like an adequate discussion, however, of the origin, nature, and possible hygienic influence of this main portion of the organic matter, could not but involve a very long story. It may suffice here to say that, having regard to its origin and nature, and to the minuteness of its proportion, the presumption against any unwholesomeness attaching to its presence is very strong. To what extent living and organised matter may be also present; how far such living organic matter may include a something capable of developing zymotic disease; and, admitting all this, how far the liability of different waters to contain more or less of noxious living organic matter is related to the varying amounts which they contain of innoxious non-living organic matter, are questions far more difficult of solution. They are questions on which, in the present imperfect state of our knowledge on the subject, it behoves every one to speak with caution; but in my own view, having regard to what is observed and recorded respecting the health of differently supplied populations, and to what little is known of the natural history of disease-producing organisms, the preponderance of evidence does not, I think, favour an alarmful answer. Other persons, however, are of a different opinion. But the address which I have been asked to read at this Conference, is on the chemistry of potable water; and my concern to-day is solely with the chemical aspect of the subject. It is not from biologic or pathogenetic inquiries, but from the results of the chemical analysis of the water supplied to London—from the mere determinations of the quantity of its organic matter—that its wholesomeness is month after month, by suggestion, impugned. On this point I join issue altogether. Further, it seems to me an abuse of chemistry, that a chemist, who on other than chemical grounds may, rightly or wrongly, have satisfied himself of the unwholesomeness of a particular water supply, should state and summarise the results of his analyses in such a fashion as to make it appear that the unwholesomeness, which he really infers on other grounds, is deducible from the results of his periodical chemical examinations. It is well understood that a statement, of which the verbal accuracy cannot be challenged, may, nevertheless, be far from a warrantable statement. It may convey a *suggestio falsi*, and include a *suppressio veri*. Such I take to be the case with the statement, paraded month after month, in what is an official, and should be a scrupulously impartial report, as to the relative "amounts of organic impurity" contained in individual samples of metropolitan water, compared with a particular decennial average amount present in the Kent Company's water,—a standard, by-the-bye, of which the value is known and used only by the reporter, whose comparison, accordingly, it is impossible to check. This monthly statement suggests, I take it, the notion that spring water is the proper type of what river water, or at any rate of what metropolitan water, should be—a notion entirely without foundation, and discordant with the reporter's own strong recommendation of lake-water for the supply of London. It further suggests the notion that the desirableness and general wholesomeness of different waters are inversely proportional to their relative "amounts of organic impurity," irrespective of the origin and nature of this so-called impurity,—a notion equally devoid of foundation. On the other hand, the statement in question suppresses the fact that spring-water, lake-water, and river-water, have each their special characteristics, excellencies, and defects. It suppresses the fact that the so-called "previous sewage contamination" of the standard spring-water is as relatively high, as its "amount of organic impurity" is relatively low. It suppresses the fact that the "amount of organic impurity" in the metropolitan river supply, though threefold or fourfold that present in the spring-water supply, is nevertheless almost infinitesimal in absolute quantity. It suppresses the fact that the "amount of organic impurity" in the highly reputed Loch Katrine supply is, during the summer months, in excess of, and is on the average of the year substantially identical with, the summer yearly amounts respectively present in the metropolitan river supply. It further suppresses the fact that the head waters of the Thames, by the time they reach Lechlade, about 22 miles only from their source, and 120 miles above the Companies' intake have exchanged their character of spring-water for that of river-water, and irrespective of urban contamination, contain an "amount of organic impurity" identical in quantity with, and chemically undistinguishable in kind from, that met with in the river-water at Hampton. I dispute altogether the notion, suggested by the mode of statement adopted in the monthly reports made to the Registrar-General, that the relative unwholesomeness of the Kent Company's water, the New River Company's water, and the Birmingham Corporation's water, was, during the last eighteen months, approximately as the numbers 1, 2, and 3; or, in other words, that it was in the proportion of the 8-hundredths, the 15-hundreths, and the 23-hundreths, of a grain of dissolved organic matter per gallon, present in the three supplies respectively. I contend, further, that the New River Company's water would have been no more wholesome or unwholesome respectively, if, instead of actually containing 15-hundreths of a grain of organic matter per gallon—this organic matter being chiefly of vegetable origin, and a product of ordinary fluviatile life—it had contained, like the Kent Company's water, as little as 8-hundredths of a grain, or like the Birmingham Corporation's water, as much as 23-hundreths of a grain of organic matter, the absolute variations of a tenth of a grain or so of such dissolved organic matter per gallon, being too small to have any real hygienic importance whatever.

If it were indeed the fact that the dissolved organic matter of potable water, taken as a whole, is of such a nature that, in the proportions in which it is met with, it is capable, on occasions, of developing and spreading epidemic disease, it is manifest that no plea, based on the actual smallness of its proportion, would be of any avail to save it from hopeless condemnation. It is manifest also, on this assumption, that the determination of the variations in the proportions of organic matter present in a water, notwithstanding the minuteness of even the maximum proportion, would be a determination of the highest significance; and further, that any information furnished in intelligible language to the general public, as to the results of a comparison of different waters with one another in regard to their respective proportions of organic matter, would have an extreme degree of interest and value. But all this is based on the hypothesis that the dissolved organic matter of water, or at any rate the dissolved organic matter of some water, taken in its entirety, is a noxious constituent of the water, capable, in proportion to its quantity, of setting up epidemic disease; a view, it need scarcely be said, which is sustained by no sort of evidence, and supported by no weight of authority. If, indeed, the organic matter of water were really of this noxious character, the conclusions above set forth, with regard to the propriety and value of a comparison of waters with one another in respect to so noxious a constituent, would be undeniable. But if, on the other hand, the minute proportion of dissolved organic matter met with in potable water is constituted mainly of innocuous vegetable extractive, with a trace or more of innocuous animal extractive; and if, at the same time, this organic matter does not affect in any appreciable degree the taste, or colour, or appearance of the water, clearly all variations in the amounts present in potable water, that fall within the limits of an exceedingly minute proportion, are matters of no consideration whatever; and this whether they be variations in the proportions existing in different waters, or variations met with in the same water at different times. And the same conclusion would hold good, even if the organic matter of water, while constituted in the main and at most times wholly, of innocuous extractive, was, nevertheless, liable to include at other times a sub-proportion of an effectively noxious agent; unless, indeed, it could be shown that the liability of different waters to contain this noxious agent was in proportion to their relative amounts of dissolved organic matter—a proposition so preposterous as never to have been seriously put forward. Whether or not there exist any good grounds for calling in question the excellence and wholesomeness of the water, supplied to probably the healthiest great city in the world, is another matter. Speaking as a chemist, I represent that there are no chemical grounds for such a contention. In support of this position, I would call to mind that the last Royal Commission on Water Supply, after hearing very varied evidence, much of it of the usual alarmist character, reported to the effect that the presence of a small quantity of organic matter in drinking water was not necessarily prejudicial; and that there was not any evidence to satisfy them that the particular organic matter present in filtered Thames water was prejudicial. Their conclusion on the general question is expressed in the following words:—"Having carefully considered all the information we have been able to collect, we see no evidence to lead us to believe that the water now supplied by the companies is not generally good and wholesome."

ON THE PURIFICATION OF WATER BY IRON ON A LARGE SCALE.

By W. Anderson, M. Inst.C.E.

In January, 1883, in a paper on the Antwerp Waterworks, read at the Institution of Civil Engineers, I described the application of Professor Bischof's method of filtration, through a mixture of spongy iron and gravel, to the purification of the waters of the River Nethe. The eighteen months' additional experience gained has shown that, so far as the purification of the water is concerned, Professor Bischof's process leaves little to be desired, but the working of the system has been costly, and the area of land required, as well as the quantity of iron necessary has, in the case of the Antwerp water at any rate, proved very much beyond the inventor's expectations.

The increased demands of the town rendered it necessary to extend the arrangements for purifying the water, and it became my duty to advise the directors of the company on the best means of doing this.

The extension of Professor Bischof's method would have involved so great an outlay, that after trying, unsuccessfully, many experiments on direct filtration through unmixed iron at high rates of flow, I determined to adopt a plan first suggested to me, some years ago, by our chairman, Sir Frederick Abel, of agitating the water to be purified with iron instead of attempting to filter it. The object, in either case, was to expose the water as much as possible to an extended surface of iron, consequently any plan by which the iron could be made to keep itself clean by rubbing against itself continually, would seem to be a more rational way of attaining this object, than of trusting to a partial filtration through a more or less spongy material.

The obstacle to trying Sir Frederick Abel's method at a much earlier date, was the belief entertained by Professor Bischof that a contact of about 45 minutes was necessary to ensure complete purification, and any such time would be fatal to mechanical means of performing the work. The late Professor Way, and Mr. Ogston, it is true, had shown that with very finely divided iron the effect was much more rapid, but there was still a doubt about its permanence.

In the autumn of last year, a revolving cylinder, 4 ft. 6 in. in diameter, and 5 ft. 6 in. long, was adapted to try Sir Frederick Abel's system. It was fitted with inlet and outlet pipes, and with shelves or ledges for scooping up the iron, raising it to the top of the cylinder, and then letting it fall through the water.

At first I began to run water through at 12 gallons per minute, which gave a contact of about 45 minutes, but I found that at this rate the water was very heavily charged with iron, I gradually increased the quantity to 30 gallons per minute, and then found that 1·20 grains of iron were dissolved per gallon, or about twelve times more than experience at Antwerp showed to be necessary. The flow was increased to 60 gallons, and even then 0·9 grains per gallon were dissolved.

The experiment looked so hopeful that I fitted much larger pipes to the apparatus, and having made some other dispositions connected with maintaining a uniform distribution of iron in the cylinder, and preventing it being washed away by the comparatively rapid current that would be possible, I sent the "Revolver," as it came to be called, to Antwerp, where it was put to work at the end of last February, and has continued to operate ever since.

The head available for forcing the water through the "Revolver," is, at Antwerp, limited to 5 feet, but by fitting very large pipes, I have managed to get 166 gallons per minute through; this gives a contact of about 3½ minutes, and is so amply sufficient, that I feel sure that, even for the waters of the Nethe, much less time will be adequate.

The charge of iron is about 500 lbs., and the quantity taken up by the water, including impurities and very fine iron washed away, during a run of 33 days, was 0·176 grain per gallon.

By making suitable arrangements, and choosing a favourable time with respect to the demands of the town, we were able to obtain samples of water that have been purified by the "Revolver" only, and after proper exposure to the air, followed by filtration through one of the large sand filters, the result obtained has been that the colour was very little different from distilled water, the free ammonia was reduced from 0·032 grains per gallon to 0·001, and the albumenoid ammonia from 0·013 grains to 0·0045.

The "Revolver" turns at the rate of about $\frac{1}{3}$ revolution per minute, and requires scarcely appreciable power. The area occupied by apparatus for dealing with 2,000,000 gallons per day is 29 feet by 24 feet, and it can be introduced into any existing system of filters, for by enlarging the in and outlet pipes to a suitable diameter, a head of some 12 inches will suffice to pass the water through.

It can easily be arranged so as to be used or not, as the state of the water to be purified may warrant, and the consumption of iron being only about 20 lb. per million gallons, is quite an insignificant expense. It will be found to remove all colour from water, whether caused by peat or clay, and will facilitate the action of sand filters by the peculiar curdling effect the iron has on the impurities.

During the experiments made at Erith, it was noticed that considerable quantities of gas collected in the upper part of the "Revolver." On collecting this gas, it was found to extinguish a lighted taper instantly, and on analysis was found to contain only 8 per cent. of oxygen.

It was observed from the first, that the animal and vegetable life which was so abundant and troublesome in the natural waters of the Nethe, lying over the spongy iron filters, had quite disappeared in the water, otherwise in exactly the same circumstances lying over the sand filters, and I always supposed that this was due chiefly to mechanical filtration through the spongy iron having separated all the germs, spores, and seeds which come to life above it. But during the recent hot weather it has been found that the water from the "Revolver," though it contains all the impurities of the natural water, has been modified by the action of iron to such an extent that neither animal nor vegetable life is apparent over the sand filters. Without presuming to draw very wide inferences from this fact with reference to the action of iron upon organisms connected with disease, it may, at least, be pointed out that the absence of visible life in water treated by iron on a large scale confirms, in a great measure, the experiments of Dr. Frankland, Dr. Voëlcker, Mr. Hatton, Professor Bischof, and others. It is due to the last named gentleman to state that to his persistent advocacy the introduction of iron as a purifier is mainly due. It must be borne in mind that the system does not depend on filtration only, but, first, on a process of exposure to iron, which decomposes the organic matter, and kills living organisms; and, secondly, on simple filtration, which merely separates the noxious matters which had been previously attacked by the iron. The waters of the Nethe are exceptionally bad, and heavily charged with impurities, so that the test both of Professor Bischof's and Sir Frederick Abel's systems has been very severe.

DISCUSSION.

Mr. W. S. MITCHELL, wished to make a remark or two with reference to Mr. Sorby's paper. The difficulty had always been to get small spores in such a form that they could be seen, but a plan had now been adopted to cultivate these spores, and in the Exhibition there were two methods shown of doing this. One at No. 193 in the Central Avenue, exhibited by Messrs. Nicholson and Mr. Carpenter, and the other in the Physiological Laboratory, where Dr. Koch's method was exhibited, which consisted of cultivation in a gelatine mixture, a kind of solid soup, and that was under the charge of Mr. Watson Cheyne. A plate of glass was taken on which some of this mixture was spread; on this a single drop of water was placed, which was then covered with glass, so that no matter from the air could reach the surface, and then the spores were allowed to grow. Some could now be seen which had been growing for fifteen or sixteen days. This method had been carried out, he understood, in Berlin for two years, but this was the first time it had been shown in this country.

Mr. JABEZ HOGG wished to say, in reference to certain remarks which had fallen from the Chairman, that he had no intention of defending the conditions of London cisterns in general, and that his remarks of yesterday applied strictly to well-covered house cisterns: he had always acknowledged that pollution must take place in uncovered tanks. He might add that in the evidence he gave at the Kingston inquiry, he stated that the small fish and eels, and other unwholesome things found in some cisterns, could not have spontaneously bred there. With regard to the paper just read, he should have been glad indeed if he could say he agreed with Dr. Odling's conclusions. The meeting, however, would have been in a much better position to discuss his conclusions if they had been put in print, and he was sorry that this had not been done, as they were in fact, the most important part of the paper. He was so far in accord with him that purity, as expressed by chemists, had a very different meaning to that attached to it by the public, and he hoped Dr. Odling would, in future, say that they must not take the purity of the water as he set it forth in his reports, to mean absolute purity and freedom from unwholesome conditions, that is from organic germs, freedom from what medical men knew to be deleterious to human life. Dr. Odling had said that the pure water of the Kent Company contained more organic matter than the water of the Thames; this appeared to be a fiction—a chemical fiction; and Professor Frankland, who originated the previous sewage contamination theory, now put it aside, and told them it had no value whatever; in fact, it had so little value, that it merely expressed something that chemists understood, and the public did not. The public were not in a fair condition to say what the chemist meant, but they know what they wanted, they wanted water perfectly free from all organic impurities, and if they got that, they cared little whether it was one grain or a dozen grains of mineral matter to a gallon. The one grain, however, which some chemists despised, was more than sufficient if it contained a specific germ, as that of typhoid fever or cholera, to poison a whole town of 40,000 inhabitants. What more did chemists require in the way of impurity? Chemists could tell us of the impurity of water; but they could not assure us of purity and safety. Chemistry could not detect the millionth, or trillionth, part of a grain of deadly organic matter in a gallon of water. That being so, it showed that chemists could only very imperfectly perform the duties undertaken by them; they could not protect the public health, as they had sometimes been led to assert. Dr. Odling had referred to the

Registrar-General's reports of June; but he had in his hand later reports, those of July, also issued from Somerset-house, and with regard to three or four towns supplied with deep well water, he noticed that Brighton had a death-rate of 13·9 to the 1000; Hull 19 to the 1000; Portsmouth 14·1 to the 1000; whilst London had 24 to the 1000. That showed that there was a considerable difference in the death-rate of towns supplied with pure and wholesome water, such as he held deep well-water to be. In London with the rise in temperature, during the month of July, there was a corresponding rise in the deaths from diarrhœa and dysentery; there were 39 in the first week, then 104 in the next, and 336 in the succeeding week. In the next month they rose again to 533, exceeding the corrected average by 242—435 were of infants under one year of age, and 78 of children between one to five. There was usually a considerable difference in the death-rate whenever the temperature of water ranged above 60 degrees, then it was that the danger of an impure drinking water was greater. He had placed on the table two specimens of deep well-water from Canterbury, one taken before being submitted to a softening process, the other after it had been softened by Clark's process. The deposit thrown down he had examined under the microscope, and could find no trace of organic matter, not even a diatomaceous body, which he expected to find under a high power.

MR. EDWIN CHADWICK, C.B., said the chemical tests for water omitted altogether what was called the biological, or stomach test, of which he might give a remarkable instance—that was that there was a change in the supply of water of the Millbank Prison from the Thames, which had formerly been used, to that of the well at Trafalgar-square, and there was a return by the medical officer of the prison, in which he showed the difference produced in the population by this change. The evidence of the benefit resulting from the change was perfectly overwhelming. In Glasgow, Aberdeen, and Manchester, all the water was found to produce dyspepsia, which chemists did not detect or take account of, but it was perfectly decisive as to the quality of water, especially during particular portions of the year. He thought it would be well if the investigation as to the sanitary results were pursued by asking the officers of prisons to note the difference produced in the health of the prisoners by a change of water ; those who have been for a time in a hard-water district, and those who were in a soft-water district, and he had no doubt that result would be obtained similar to those recorded in the instance he had referred to at Millbank, and which were utterly unnoticed by any chemist at present. Again, the Chairman would know very well how the quality of water depended on its aëration. At Pangbourne you might take up water, and find it quite brilliant, showing evidence of good quality, but when that same water was taken to London, and put into a cistern where it came in contact with the air of the cistern, your were really drinking down air with all the impurities which were likely to arise. In going into overcrowded rooms, or low neighbourhoods, medical officers would tell you that in washing, after an operation, their fingers quite smelt of the water they obtained there. He recollected on one occasion, when making an inspection in Rotherhithe, the medical officer cautioned him against taking any water there, for it would be dangerous, because the water beds were situated close by the cesspools and absorbed the cesspool air. Some years ago, he asked Dr. Hofmann if he could analyse a London fog, which carried disease with it ; but he could only separate the dust and dirt, and he failed to analyse them. Again, with respect to the paper which spoke of the protection of rivers by the action of plants, he would point out the immense difference between fresh sewage and that which was putrid. When the houses of a town were drained, or water-closetted, so that the sewage discharged fresh, it was noticed that fish returned to the river which they had forsaken. That had been noticed at Carlisle—the fish reappeared, and were finer in quality altogether.

Mr. BISCHOF said it had been a point of the greatest interest to him to learn that spongy iron, after a very few minutes' contact, had such a powerful effect in destroying animal and vegetable life. Mr. Anderson had said that his anticipations at Antwerp were not quite fulfilled, and that was quite true; but he never anticipated the difficulty which had been experienced there. To deal with a small tidal river contaminated with all kinds of polluting matter, and to convert such water into a potable water, every one would admit was a matter of the greatest difficulty. However, the plan introduced by him had been styled a "complete success" by the Chairman of the Antwerp Waterworks Company, at the last general meeting. Dr. Odling had been speaking under great difficulties as regards time, no doubt; but to him, as a chemist, it would have been of much interest if he could have given some hint as to how he arrived at the statement that organic matter in water might be said roughly to contain 40 per cent. of organic carbon. As a chemist, he could scarcely conceive that there should not be an enormous difference in different organic matter, because some water was contaminated largely—in fact, almost exclusively—by animal and other water by vegetable matter, and they all knew that animal and vegetable matter differed very greatly in the proportion of carbon they contained. He wished to refer to only one more point. He had in his hand the return of the Registrar-General for July 20th, 1878, which stated :—"The weekly deaths from diarrhœa and simple cholera, which had been 23, rose to 78, 156, 256, and 349 in the corresponding weeks. The deaths from diarrhœa are differently distributed in the fields of the water companies. Thus, the deaths in the last four weeks were 786 in the districts supplied with the Thames and Lea waters, whereas the deaths in the districts supplied with water drawn from the chalk by the Kent Company were 19; but of the same population, the deaths in the former were to the deaths in the latter as 3 to 1." As there might be a visitation of cholera this autumn, and as they all agreed that diarrhœa and simple cholera, although totally distinct from Asiatic cholera would still predispose to it, this was a point of very great interest, and he should be glad if Dr. Odling, or any one else, would express an opinion whether these figures which he had just read did not throw an important light on the relative wholesomeness of the different supplies of water to the metropolis.

Dr. BARTLETT said, one observation made by Dr. Odling very naturally led up to the few words he had to say. He stated that certain water, when thoroughly filtered, would then be good enough, and pure enough, for all potable purposes; another leading observation was made in Mr. Anderson's paper, namely that by mixing iron in a very finely powdered state with water, a far greater efficacy was obtained than can be in the ordinary way, by passing it through coarse filter beds or compressed blocks of porous iron or other filtering substances. He so far cordially agreed with that statement that it formed the very pith of what he wished to say. At the present time the question of filtration, whether in the water companies' sand-beds, or in the domestic filters which persons now used for the purpose of correcting any omissions on the part of the companies, was highly prominent. One section of the public appeared to rely entirely on this process, and another semi-scientific section were apt to place no reliance whatever on it. It had been stated, over and over again, that filtration could not remove matters in solution, but only those in suspension; but to that statement he took objection, because during the last ten or fifteen years, in the process of testing a great number of filters—in fact, almost every kind which was presented to the public—he had found, that to a lesser or greater degree, nitrogenous matters in solution were removed. The manufacture of filters, and the scientific application of filtering media, had improved, but although he said this with great confidence that there were filters which would remove nine-tenths of the nitrogenous matters in solution, still, he was equally certain that nine-tenths of the filters before the public were perfectly worthless, because with the tenth part of nitrogenous matter which was not removed there was that amount of unfiltered water passing through into the storage receptacle. Now, if the tenth which passed through contained any of the germs of disease, or communicable matter of disease, whether germs or not, that would be equally as fatal to the drinkers as if it were entirely unfiltered water. He had been led to this train of reasoning more particularly because during the last six or eight months he had been testing filters which removed nine-tenths of the decomposible organic matter; and the other tenth would have been removed had the filters been mechanically perfect. He had been making experiments on a very fine precipitate, sulphate of barium, and found that that freely passed through many of the filters, and therefore it became obvious that matters which were very much smaller than that would equally pass through. He then went on with salts of uranium, a still finer precipitate, and found they almost invariably went through. Then it occurred to him it would be well to try if he could not stop this. Both these salts were white, and, therefore, were perfectly visible to the naked eye, or, in the finer particles, under the microscope. He tried to stop it by using finely powdered carbon, animal, vegetable, and mineral. The result was that he found that with carbon of all three kinds, when reduced to much finer particles, they also came through the greater part of the filters he tested with it. This was most important, because anyone could go home and make similar experiments for himself. In working this out, he found after having used a considerable amount of very fine carbon, he had stopped very nearly the whole of that one-tenth of decomposible matter, and in fact he had decomposed the greater part of that tenth. Knowing the oxydising influence of spongy platinum, he went one step further, and used platinum black. Of course he would not recommend this as being suitable for ordinary filtering purposes, because of its expense, and there might be other objections also; but it did absolutely oxydise and remove every trace of decomposing nitrogenous matter.

That being the case, it was certain that perfect filtration could be obtained. Following this up, he had tried carbon in the finest divided state, so fine that he found by the microscope the particles were finer than the markings on a diatom, for under a 50th power he could not measure them, although he could measure the markings of diatoms. Carbon, therefore, could be obtained, if necessary, in so fine a form of sub-division that an immense amount of oxydising power was thereby obtained. It might be said, how were you going to filter water through that extremely finely divided carbon. He thought possibly that cotton wool, which obstructed all germinal matter passing through, as was shown in the well-known experiments of Professor Tyndall and M. Pasteur, was a means to the end, but soon afterwards he found that cotton wool decomposed in water, and therefore that upset the experiment. He therefore tried two other media, one a peculiar kind of slag wool, and the other asbestos fibre, both of those retained the finest particles of charcoal, and formed a perfect filtering medium as far as developing the oxydising property of finely divided carbon was concerned. Having obtained this result, he must add that he was not aware of any filter now before the public which had no decomposing matter in its construction. The introduction of the cork caused decomposing matter to be mixed with the water, and under the microscope large quantities of moving organisms were to be found in the decomposing matter of the cork itself. The same thing, in a lesser degree, occurred with india-rubber, and, therefore, he laid it down as a fundamental axiom in filter-making that no decomposing matter of any kind should enter into its construction. Further than that, the filtering media should neither pass the finest possible charcoal, nor should they be choked up by it. These two points formed the most important tests he had to bring forward. If they fell back on the old plan of testing filters which we had been in the habit of using for twenty years, they would be misled as to the mechanical deficiencies of which he had spoken of, for it was no use whether one adopted Dr. Frankland's process for the analysis of water, or the estimation of ammonia, to suppose that because you were able to oxydise three-quarters, or even nine-tenths of the decomposible nitrogenous matter, that the filter itself was therefore of any value. If this were recognised, and people would make the experiment for themselves, he believed better filters would be produced, as purchasers would be able to test the filters by these means. There would be at last a possibility of arresting much of that which was injurious to health; and it was not impossible that they might prevent even the smallest germs, which must be of some size, passing through the very fine medium he had suggested.

Mr. THOMAS SPENCER said they had heard a great deal of the necessity of softening water, and a great many processes for effecting that purpose had been mentioned, but they had heard nothing as to the physiological difference to the animal system of very hard water and very soft water. For forty years he had been going through most of the towns in England, and he could never get that question answered—what was the physiological effect on the system of hard water, as hard as that supplied by the Thames, as compared with soft. He might say that he knew most of the water supplies of the world, and he did not know of a better supply anywhere than that which came from the Thames when properly filtered; he did not mean by any chemical means, but when well filtered mechanically. He had constructed waterworks at Calcutta, and knew many of those on the Continent, and if the Thames water were well filtered, it would be one of the best water supplies to any large town in the kingdom. When he put that question he never got a reply, but was told he did not require any explanation—that salts of lime and magnesia were not desirable. Two years ago, he suggested to the authorities of a town with which he was connected, that to settle this question it would be well to get accounts from the authorities of the different towns, and ascertain where the death-rate was highest—whether in towns having a soft water supply, or hard water. That report had now been returned, and no doubt would be in print before long, when it would be found that the death-rate was larger where soft water was used, and this to a much greater extent than he had anticipated. He must say also that he began as a soft water fanatic, but there was no doubt that one reason why soft water was so much recommended was that in many of the towns in the north, calico-printing, and similar works were very numerous, and as soft water was much better for such operations, people naturally supposed that similar water was better for domestic purposes.

Mr. MAIGNEN said he had hoped some paper would have been read on the subject of filtration as a whole. They heard a good deal of how water was contaminated in a very astonishing way, but how to get over the difficulty they had heard very little. He could not attempt to do justice to the matter in the very few minutes he had at his disposal; but what he had to draw attention to was this, that on Thursday last he was in the laboratory of M. Pasteur in Paris, who asked him " how will your filter last ?" Now this was a subject worthy a whole day's discussion. The first necessity of filtration was that, when impurities had been collected in the filtering material, it could be easily removed, and thrown away and replaced. Dr. Bartlett had knocked the nail on the head by drawing attention to a very important fact. If a microbe had a body, it was just possible to conceive an impediment, or a series of impedimenta, fine enough to prevent it passing through. Dr. Bartlett told them that he had used charcoal the particles of which were smaller than the smallest known diatom, and if these particles did not come through a particular form of filter, it was conclusive that the diatom itself could not pass through. He echoed the statement made by one of the speakers, that if the London Thames water were properly filtered, it would be the best in the world, and he had reason to hope that this would soon be attained by means of the apparatus shown on the wall.

Dr. HAUGHTON said a great deal had been said in favour of the water they were obliged to drink in London, there being no option as to the source from which it was obtained ; and he wished he could heartily endorse all that had been said in its favour, because it was unpleasant to have a bad opinion of that which one had to deal with continually. He listened to Dr. Odling's paper with great admiration until he came to the last sentence ; but they were not told there whether his estimate of the London water as compared with the supplies of other towns was founded on its present condition, or on some former period, or on a fair average. He had in his hand an extract referring to the condition of things at the time of the epidemic of 1830 ; but it was written twenty years later, and those periods were not referred to with reference to the microscopical analyses and examination of the water. It stated that at this time there was hardly a water company in London the water of which did not reveal to the microscope solid particles of sewage floating about in the company of small weeds and sponges, and fine fat pulpy animalcules. At an interval of twenty years there was the same condition ; and it was obvious that when such things had happened they might happen again, especially when eels and fish were found in reservoirs where they were not bred. It was not at all infrequent in disputed cases in the Law Courts for chemists to give evidence with regard to the supposed condition of streams ; when one would state that the water was dirty, and another would say it was beautiful, and both had made analyses, and both were men of science. With regard to the basis on which this statement with regard to London water was founded, it appeared, so far as he could make out, that the ground upon which Dr. Odling claimed this wonderful excellence was the very ground which, in the earlier part of the paper, he said it was totally inapplicable to put before the general public. For if he only got the chemist's estimate of the amount of organic matter, and that was put forth to the general public as a test for the quality of the water in order to re-assure the said public that the water they were drinking was beautiful, they found Dr. Odling himself saying that it was not a reliable test. Yet at the end of the paper he said London water was very superior because of this very thing, for he brought no other evidence. That appeared to his mind very unsatisfactory, speaking not as a medical man, but as one of the long suffering public who had to drink water which had been testified to be contaminated, not far from the intake of the companies, with organic matter of the foulest description. It was true those cases were not very flagrant, except at particular periods, but they wanted a guarantee that they should not occur at all. What was the use of talking about filters, and telling the public the water was unfit to drink unless it were filtered. It was the grossest cruelty to the poor. They could not buy filters, and even if they were distributed gratuitously, there was not one family in ten who would take care of them, so as to see them renewed. You might filter out the cats and dogs, and the grosser particles of matter; but the better the filter the sooner it became filled with germs, and every kind of contamination. It was the very nature of a filter to become filled with foulness, to breed microbes, to become itself a source for contaminating the water, if it were not renewed within a reasonable time. The gentlemen who spoke so much in favour of filtration had an idea, which was good in itself, that the filtering medium should be so arranged as that it could be renewed; but to say that the general public were to depend on any kind of filter, patent or not, was stark nonsense. This evil was not imaginary, for it was given in evidence before the Metropolitan Medical Commission in 1830, that whenever water was contaminated so as to be nauseous, diarrhœa was invariably prevalent, and affected the health of every person drinking it. He did not want to increase the cholera scare, but he hoped to utilise it, by demanding of the authorities that no money should be spared to give a good supply of water, which should be available for every house in the city, without putting a single inhabitant to the expense of a filter.

Dr. ODLING, in reply, said he had been invited to read a paper on the chemistry of water, and had, therefore, confined himself mainly to chemistry ; and for this, under the circumstances, he did not think he was to blame. At the same time he might say that for many years he was a medical officer of health, and had since attended to hygienic studies, and he came prepared to speak not only as a chemist, but also as a physician and hygeist. As regarded the general question, the influence of the presence of organic matter in water must depend, not on its quantity, but its nature. And any comparisons put forward with regard to quantity, irrespective of nature, fell to the ground altogether. Had there been sufficient time, it was his intention to discuss the question of quality as he had the question of quantity ; and he had notes ready for the purpose, but time did not allow of their use. Any general statement, and any conclusion he had formed or expressed, with regard to quality, was formed on a consideration of evidence, and was gone into by him as minutely as he had gone into the question of the influence of quantity. The gist of the whole question in the present state of knowledge seemed to rest on an observation of effects. Of course if you took one week and compared it with another, or one town with another for a short period, you might arrive at almost any result you pleased ; but if you took large populations, and examined the statistics for lengthened periods; it would be found that there was absolutely no difference whatever in the health of the population which could be ascribed to the drinking of river water, or spring water ; from which it would seem all these different varieties were, in their different ways, well suited for the supply of large populations.

III.—METHODS OF DISTRIBUTION. MODES OF GIVING PRESSURE, HOUSE FITTINGS, DISCOVERY AND PREVENTION OF WASTE, ETC.

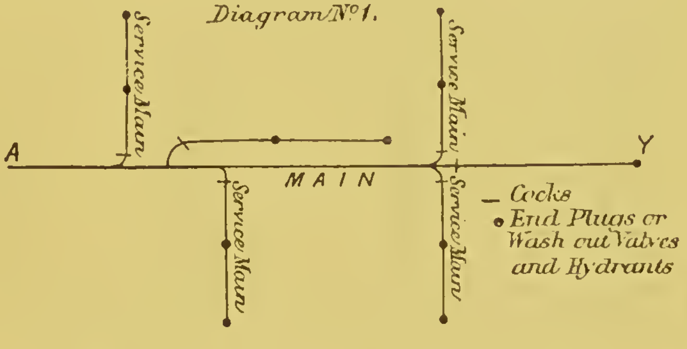
WATER DISTRIBUTION AND DUAL SUPPLY.

By Col. Sir FRANCIS BOLTON.

In former times it was customary to lead water through aqueducts to public fountains, whence it was taken by water carriers to those consumers who could afford to pay for it, while the poorer classes fetched the water from the fountains for themselves ; and this system still exists in certain large cities abroad, such as Constantinople and Venice. In some towns, indeed, even in ancient times, this primitive mode of delivering water was found insufficient for the better class of houses. In luxurious Pompeii, for instance, which was destroyed A.D. 79, a very complete system of distribution appears to have existed by means of pipes, which delivered the water direct to the houses. This mode, however, was by no means general, the inhabitants of most cities contenting themselves, as above mentioned, with the services of water carriers.

A very noticeable want in connection with those towns which derive their water supply from public fountains is that they are, for the most part, without any sewage system, and the evils arising from this serious drawback may be readily imagined, although it is not the object of this paper to describe them. On the other hand, it should be mentioned that the difficulty of carrying large quantities of water in such towns to the houses separately has, from time immemorial, been remedied to a certain extent by the construction of public baths, and other public conveniences for the general health and benefit of the inhabitants.

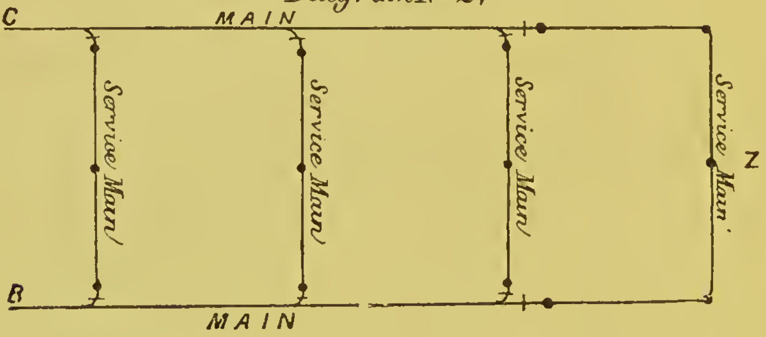
The mode of distribution which may now be said to be almost universal is by means of cast-iron pipes, and as far as our knowledge goes, in the present state of hydraulic engineering, this system may be considered perfect. Towns are divided into districts, according to position and level, and in each district mains are laid, usually following the course of the principal streets. From these mains service pipes supply all the streets within the area. Each service pipe is provided with a cock at the junction with the main, and a wash-out valve at the other end, fire-plugs or hydrants being inserted at convenient distances, usually about 100 yards apart. In those districts which are supplied on the intermittent system, the service-pipe cocks are opened and closed at certain intervals; but where the plan of "constant supply" is adopted, they are always left open, except in case of accident, or during repairs.



On reference to Diagram No. 1, showing part of distributory mains on this system, it will be seen that the water, on entering the service pipes, enters as it were a *cul de sac*, where, unless there is a large draught or consumption, it is apt to remain practically stagnant, thus allowing the impurities held in suspension to be deposited on the sides and bottoms of the pipes. It is for this reason a wash-out valve is placed at the end, which, if opened sufficiently often, allows the impurities to be washed out; but if this precaution is neglected, the impurities accumulate, and when a sudden call is made on the service pipe, find their way to the consumer.

By having no "dead ends," as shown in Diagram No. 2, this difficulty is obviated, as the water is continually circulating in all directions. This arrangement is of great advantage where there is constant supply, as in case of accident at C, the main, B, would supply the service pipes entirely whereas if an accident occurred at A (Diagram No. 1), the whole district beyond would be without water until the repairs were completed. It has the further advantage that should a fire occur at Z (Diagram No. 2), both mains, B and C, would supply that and the adjoining hydrants, whereas a fire occurring at Y (Diagram 1), would only have the water passing through the one pipe. Equal facilities occur for washing out the service pipes, if found necessary, by closing the cock and opening the adjoining hydrant.

Diagram No. 2,



The pipes should be of iron, of good tough quality, as, if the metal is brittle, difficulty is found in cutting the holes to receive the house service pipes; 2 inch pipes are usually cast in 6 feet lengths, 3 inch to 12 inch, 9 feet length, and 12 inch, and upwards, in 12 feet lengths. In order to ensure uniform thickness, the pipes are generally cast upright, and socket downwards; and to prevent oxidation of the interior, they generally either receive a coating of lime inside, or are dipped whilst hot into a mixture of pitch, oil, and tar, which is usually known, from the name of the inventor, as

Dr. Angus Smith's composition. The protection of the interior of the pipe is particularly necessary if iron is used in the filtering medium, as otherwise the water becomes distinctly chalybeate if the consumption is slow.

The mode of connecting the pipes together is by slipping the spigot end of one pipe into the socket of the next, and then making the joint. Diagram No. 3 shows the ordinary method of joining pipes. No. 1 is the ordinary "yarn and lead" joint, and No. 2 the "turned and bored" joint. In No. 1 the best white yarn is caulked in to a depth of about 2½ inches, and the rest of the space run in with soft lead, which is afterwards well set up or caulked one-eighth of an inch within the rim of the socket. The chief point to be observed is that no part of the yarn should find its way into the interior of the pipe. In No. 2, the turned spigot is simply brushed with cement or paint, and pushed home into the bored socket. The extra space is sometimes run with lead and sometimes left. The most approved modern system is to run the joint solid with lead without the yarn, a strip of drawn lead being inserted in the bottom of the socket in lieu of yarn.

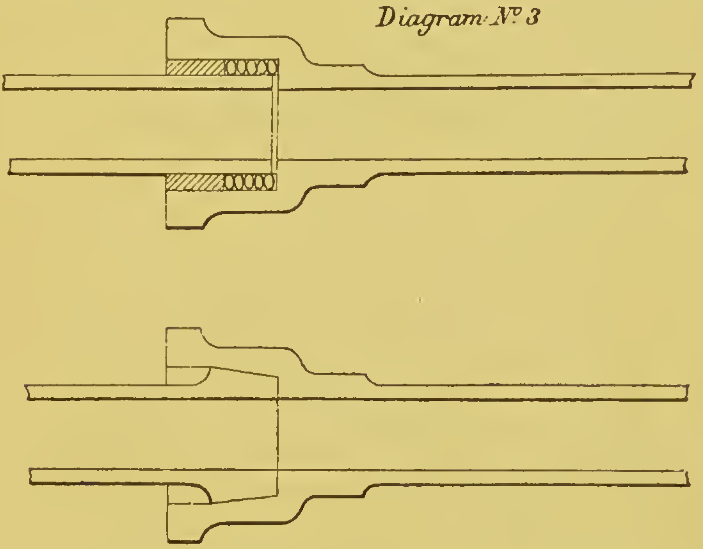
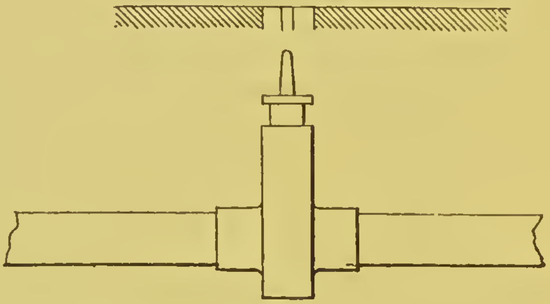


Diagram No 3

For connecting the service mains suitable cast-iron branches are introduced. The cocks used for regulating the flow of the water consist of a door, which is raised or lowered by means of a screw worked from the surface, as shown in Diagram No. 4. For the purpose of supplying water in case of fire or other emergency, openings are left in the mains, which are closed in some old waterworks by wooden plugs, but in all recently constructed ones by hydrants, which are undoubtedly to be preferred. The description of these, however, properly belongs to the section treating of the supply of water for extinguishing fires, and a full account of the various forms in use will be found in the special paper on "Water Supply for Fire Extinction," by Mr. J. H. Greathead, C.E.

Diagram No. 4.

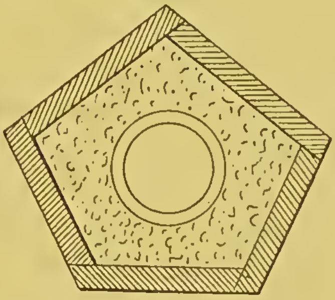


Each house is connected with the service pipe or main, by a pipe called the "house-service pipe," the connection being made by means of a ferrule screwed into the main. The house-service pipe is generally of lead, but as some waters have a chemical action upon this metal, drawn-iron pipes, either glazed, galvanised, or otherwise protected, are substituted. Where the system of "constant supply" prevails, an apparatus is used in order to avoid inconveniencing the consumer, which enables the ferrules to be inserted while the main is still charged and under pressure.

The depth at which mains should be laid varies according to circumstances, but may be taken in temperate climates to be from two to three feet from the surface of the ground to the top of the pipe. In colder climates the mains should be laid at sufficient depth to escape the action of frost, which, generally speaking, does not extend below four to five feet. When mains are laid at this depth, the cost of laying as well as making house connections and effecting repairs is considerably increased. When the temperature of the water varies considerably at different seasons, the length of main is affected. Where "socket joints" are used, little damage is done, but with "turned and bored joints" it will generally be found in autumn that some tightening up of the joints is necessary, unless special provision is made for the contraction that then takes place.

Where pipes are carried across openings they should be protected from the changes of temperature, which can conveniently be done as shown in Diagram No. 5, in which the pipe is shown enclosed in a wooden casing, the circular space being filled in with felt, sawdust, or other non-conducting material. In laying mains across bridges, great care should be taken for their protection. It will often be found that there is not sufficient depth from the surface to the arch or girder of the bridge to allow of the pipes being laid ; when this is the case, it is convenient to carry the mains on cantilevers at the side of the bridge, the pipes being enclosed in a casing of wood or other material, as shown in Diagram No. 5. In new bridges it is generally arranged to leave sufficient space for a subway below the footpaths ; this, as a rule, is a very convenient way, as it allows of repairs being effected without interfering with the ordinary traffic.

Diagram No 5



The system of distribution hereinbefore described refers mostly to the distributing pipes within the town. In some exceptional cases, owing to local circumstances, wooden pipes, similar to those which were used before the introduction of iron pipes, are still used, and in places where freight and carriage are difficult, pipes formed of sheet iron or steel can, owing to their lightness, be more economically used than those of cast iron. Pipes have been made of paper prepared with bitumen and several other substances, but have not been proved able to withstand the severe tests to which water pipes are subject. Where the pressure is very great, as for instance where water is distributed for hydraulic power, the pipes are cast of extra thickness, and a "faced" flange joint with an india-rubber ring inside a recess, into which a projection on the next pipe fits, is sometimes substituted for the socket joint.

The construction of the aqueduct conveying the water from the source to the distributary mains varies with circumstances. If the water is conveyed under pressure, one of iron is necessary, and preferably of cast-iron, which, being laid under the surface of the ground, is better in all respects (apart from cost) than any other. The pipes are so placed as to follow pretty closely the undulations of the ground, an emptying valve being fixed at the bottom of every fall, and an air escape valve at every summit. When large quantities of water, however, have to be conveyed, aqueducts of masonry, brickwork, or concrete, have to be adopted. These, unlike pipes which can be made to follow the inequalities of the ground, have to be laid to a regular gradient. Provision is made for draining such aqueducts, and overflows are placed along their length to prevent damage in case of the flow of water being interrupted. All aqueducts of masonry, &c., should be covered, but this is not always possible when they are of large size. Size, indeed, renders the covering less necessary, provided precautions are taken to prevent the infiltration of land drainage, as the large quantity of water flowing down is less liable to be affected by the sun, while the conduit, being uncovered, can be easily and completely cleansed at all times.

The cross section varies with the materials employed; those of brickwork and concrete being generally of an oval or circular form, whilst those of masonry are usually constructed with a rectangular section, and when covered, are sometimes arched over, and sometimes covered with slabs. For the aqueducts, tunnels often have to be made through hills, and conduits over valleys. These latter, when there is sufficient head of water available, are usually crossed by syphons of cast-iron pipes. When, however, the head of water cannot be spared, the aqueduct is carried across the valley at the regular gradient, and supported by piers of masonry, or other suitable material. In this case, the aqueduct is sometimes continued in masonry, brickwork, or concrete, or a trough or tube of wrought iron is substituted. This trough is sometimes made of pipes of sheet iron or steel, riveted together throughout the full length of the crossing, and suspended and braced by wire cables or rods, similarly to a suspension bridge.

One of the most important of modern aqueducts is that bringing the water of the River Vanne to Paris, the length of which is about 90 miles, with 23 syphons of wrought-iron pipes.

The chief points to be observed in the designing of a complete distribution should be—(*a*) that the water, which before entering the mains is in its purest state, should be delivered to the consumer in a similar state, and suffer no contamination on the way; (*b*) that the mains should be of sufficient area to allow an ample quantity of water to pass to meet all contingencies; and (*c*) that a constant circulation should be maintained of about 3 ft. per second so as to prevent any deposit taking place.

DUAL SUPPLY.

In the case of many large towns, an abundant supply of water of inferior quality is found in close proximity, while further off, but still within reasonable distance, a limited supply of better water exists. In considering such cases, it often becomes a question as to the advisability of adopting both sources of supply, the latter for drinking purposes, and the former for domestic and manufacturing uses. In the opinion of the writer, a system of dual supply is not practicable for domestic purposes, but only for municipal or manufacturing requirements. In cases where water is used for power, a dual supply may also be considered indispensable, as the great pressure necessary for its economical use for this purpose is undesirable for a domestic supply. Again, a separate supply for municipal purposes can be used for road watering, sewer flushing, fires, &c., without affecting the domestic supply. In most manufacturing towns the factories are grouped together, and require large quantities of water at a very cheap rate, which, supposing the water is not used in any way for alimentary purposes, can often be supplied from sources sufficiently pure for purposes of manufacture, although the water may be unfitted for household consumption. Such a supply exists at Roubaix, in France, where the cheapness of the water contributes to the prosperity of the town.

Paris also is supplied in the same manner, there being a double set of mains in the streets, one for domestic purposes, and the other for street watering, &c. The supply of potable water, however, is limited, and in time of drought has to be supplemented by water drawn from the Seine.

A dual supply for domestic purposes would entail a considerable extra outlay on the construction of works, as a double line of mains would be necessary in every street, and the cost of most of the house fittings would be doubled, as they would have to be in duplicate. Another objection is the probability that the excellent quality of the water supplied for potable purposes would cause the quality of the other to be little considered, and the latter might deteriorate, or become subject to great contamination. Consumers, bearing this in mind, would probably use the purer water almost entirely. In ordinary times, this might not be of much consequence, but in times of drought it might be serious. This difficulty, it is reported, has just occurred in Paris, which, as just stated, is supplied under this system, and where now, in the heat of summer, with the cholera possibly approaching the town, the drinking water is said to be failing, so that nearly all the supply will have to be taken from the other source, the Seine. Unfortunately, this water is not as carefully filtered and aërated as it would be if it were usually used for domestic purposes, and it may consequently prove a source of danger and disease.

When only one supply exists for domestic purposes, means are generally taken to render it as pure as possible, either by efficient filtration, or by such other means as may be found necessary. Should such water not be considered of a sufficiently high standard of quality, a pure source is selected, and the old one abandoned; when this is impossible, the use of household filters becomes universal.

When the Chelsea Water Company first moved their intake to Ditton, in carrying out the works an extra reservoir was constructed, and extra mains were laid for supplying unfiltered water for road watering and other purposes, but in practice this arrangement was found to be no saving, and to possess no advantage over supplying filtered water for these purposes, so it was discontinued, and now none but filtered water is supplied.

It may be contended that if water were sold by meter, the difficulty of supplying the two kinds of water for domestic purposes would be overcome, inasmuch as the extra cost of the purer water would prevent its excessive use, and so conduce to its conservation and the greater use of the inferior water. This argument, probably, would prove fallacious, as the servants who use the water are unaffected by any such considerations.

It might, further, be urged that the inferior water should only be laid on to the closets, and that the supply to them should be independent of the general domestic supply. This arrangement would leave the remainder of the domestic supply to be furnished by the better water. Baths even would have to be supplied from it, for when it is remembered that they are very frequently supplied with hot water from an apparatus from which water is drawn for other purposes, it will be seen that it would be practicably impossible for them to be connected with an inferior supply. Apart from special cases, in which water is distributed under great pressure for power, and under smaller pressure for ordinary consumption, only one plan of dual supply seems feasible, which, however, from the necessity for duplicate mains, &c., must necessarily be costly, though it might prove advantageous in many respects if carefully worked out. The writer would hesitate to advise such a scheme, except under exceptional circumstances. It is that the domestic supply should be entrusted to a company selling water by meter, and the general supply (including supplies to closets) should be in the hands of the municipal authority, and paid for by a general rate levied on all property. In addition, the municipal authorities would receive payment for any water they might dispose of for manufacturing purposes. It will be seen that, under this arrangement, the municipal authority would have under its control water-works (supplying fairly good water it must always be presumed) for supplying closets, road and public garden watering, sewer flushing, fire extinguishing, and to sell for manufacturing purposes. The company which supplied water by meter for domestic use, and for those manufacturing purposes for which pure water is indispensable, should also be under the supervision of the municipal authorities.

Such a system as the above would probably only be found worthy of consideration in the case of a town which possessed a supply of good water, but of so limited a quantity that the rapid growth of the city rendered an increased supply indispensable, and where there was an inferior supply near, which could be made available at small cost. By these means the consumption of the pure water would probably be reduced to such an extent as to be available for a much larger population, and at the same time, from the fact of the municipal authorities controlling the house drains, closets, and flushing supplies, an improved sanitary condition might result. It is, however, not easy to imagine a town in such a position.

Rain water, as it falls, is in a comparatively pure state, and if proper measures are taken to preserve the surplus falling in wet seasons, and to keep it from contamination, it will generally be found that the rain falling in each watershed is amply sufficient to supply the whole of the inhabitants dwelling in their districts. If any scarcity exists, it is owing, generally speaking, to the want of proper care, or to the fact that the district is so subdivided under different authorities, that joint action for the proper conservation of the rainfall is impossible.

MODE OF DISTRIBUTION, WITH SOME REMARKS ON DUAL SUPPLY.

By HENRY J. MARTEN, M.Inst.C.E.

UNTIL comparatively recent times no attempts were made to afford what we now term "a domestic supply," that is to say, a supply of water distributed to and available within each house for general domestic purposes.

The large supplies of fine water introduced into the principal cities of ancient times, by means of the magnificent aqueducts of which there are many remains to this day, were directed, so far as distribution is concerned, to the supply of public baths and fountains, and possibly here and there to the supply, for similar purposes, of a few of the private residences of the wealthy classes.

A house-to-house supply, such as we have in modern times, was unknown and undreamt of. The supply for domestic purposes had to be obtained by the occupants of the houses either from the public fountains, or from the streams flowing from them, or was supplied in detail by water carriers, somewhat after the fashion in which milk is now supplied from house to house. Although, according to Pliny, the ancients were aware that water under pressure rises to the height of its source, little practical advantage was taken of the knowledge of this fact. Water under pressure was occasionally conveyed for some distance through stone or earthenware tubes or in leaden pipes. The two former were, however, difficult to be kept tight, and the latter were not only very expensive, but, at an early period of their history, were found to act deleteriously on the water flowing through them. Although, therefore, immense volumes of water were frequently brought into ancient cities, as into Rome, where, according to Strabo, "whole rivers flowed through the streets," and where the total quantity so delivered probably exceeded three hundred gallons per diem to each inhabitant, there was practically no distributed domestic supply.

The inhabitants of modern London, therefore, although only furnished with a supply per head equal to one-tenth of that which used to flow into old Rome, are nevertheless infinitely better off than the ancient Roman, because the thirty gallons supplied to the modern Londoner are delivered exactly where he requires it, "upstairs, downstairs, or in my lady's chamber," and the supply is at all times available by the mere turning of a tap. We have here a good illustration showing how various combinations of applied science, united to the practical skill of modern times, have resulted in a tenfold economy, coupled, at a moderate estimate, with a tenfold advantage to the water consumer.

If modern London were supplied in the same wasteful and unscientific manner as ancient Rome, the quantity of water required for the purpose would exceed in volume the average flow of the River Thames at Kingston, and whilst this immense volume of water would be rushing from public fountains, and down open channels made for the purpose in the streets, the inhabitants would be totally without the comfort and advantage which they at present enjoy of a domestic supply delivered under pressure into each of their houses.

Coming to modern times, the distribution of a domestic supply dates back from the time of Peter Morice, who, in 1582, erected waterworks for the supply of the City of London by means of pumps actuated by water-wheels placed in the first two arches of old London Bridge. He appears to have distributed the water under pressure through leaden pipes, but it is probable that a few years later these were replaced by wooden pipes, which, as early as the year 1628, were being laid down by the New River Water Company. These wooden pipes consisted of the trunks of elm trees, cut into lengths and bored longitudinally to an internal diameter of from 6 to 12 inches, in accordance with the internal pressure they were required to withstand. In the parts of the town lying at the lower level (where the pressure would be greatest), the diameter of the bore would be 6 inches, so as to leave a considerable thickness of wood between the inside of the bore and the outside of the tree. In the higher parts of the town, and near the reservoirs, where the pressure would be less, the bore would be gradually increased to 12 inches in diameter, a less thickness of timber being required in those parts. The joints of these wooden pipes were made by forming one end of the tree into a conical shape, and hollowing out the other to correspond ; the several lengths, when laid, being then driven one into the other.

These wooden pipes, however, proved very defective, as the loss by leakage was estimated at not less than one-fourth of the whole quantity flowing through them. From decay and other causes they required also to be renewed on the average about once in every twenty years ; and consequently, as at one time the New River Company had 400 miles of these pipes laid down, they had to take up and renew upwards of 20 miles in length each year.

Owing also to the small diameter of these wooden pipes, where they had to bear any amount of pressure, more than one line—and in one case no less than nine lines—of pipes had to be laid side by side in the same street, in order to furnish the requisite supply.

When we reflect on the fact that at this period London was almost entirely without under drains, we may be able to form some slight idea of the terrible amount of moisture with which the foundations and basements of the houses adjoining these lines of leaky pipes must at all times have been saturated, and the disturbance which the constant repair and renewal of these pipes must have occasioned to the roads.

Bad, therefore, as matters are at the present time in London and other large towns, from the disturbance of the streets for such repairs, we of the present generation may congratulate ourselves upon the fact that, notwithstanding we now have gas-pipes, sewers, and under-ground electric wires in addition to water-pipes laid under the streets, the annoyance which we suffer from street disturbance is as nothing compared with that which our ancestors must have had to put up with in this respect.

There are no records to which the writer has access showing whether, in these early times, the supply for domestic purposes was on the constant or the intermittent system, nor whether the water was delivered at the ground floor of each house only or at a higher elevation. With wooden distribution pipes, such as these described, it would be very difficult to have a proper service of stop or shut-off valves, even if an efficient stop-valve for working under pressure were then invented. The frequent stoppages for repairs would necessarily assimilate the arrangements for supply to those of the intermittent system, which involves the necessity of having tanks, butts, or other capacious receptacles for the storage of water in each house.

In the early part of the present century, cast-iron mains began to be substituted for wooden water-pipes, and by the year 1820 the whole of the wooden pipes belonging to the New River Company had been removed and replaced by cast-iron ones. The substitution of cast-iron for wood introduced a new era into the art of water distribution, as much higher pressures were rendered available, and leakage was materially reduced. The early cast-iron pipes, although made of the finest cold blast metal, were very rough productions. They were all cast horizontally, and in numerous cases, owing to the imperfection of the machinery, they were far from being either cylindrical or concentric, and thus were frequently thicker on one side than the other. They often, therefore, gave way when exposed to the working pressures they were called upon to sustain, the methods of testing them previous to their being laid being primitive and inefficient.

The first cast-iron distribution pipes were made with flanges on the same principle as the ordinary cast-iron pump-trees. These flanges were fastened together with bolts and nuts, the joint being made between the flanges, with an iron ring covered with tarred yarn or flannel. This method, however, soon had to be abandoned, as owing to the expansion and contraction of the pipes consequent on the changes of temperature in the water passing through them, the flanges were frequently torn off, and hence stoppages for repairs were numerous.

This defect was overcome by the introduction of the spigot and socket-pipe. The early joints of these pipes were made by driving soft wood wedges into the sockets, which were made wide for the purpose. When the wedges had been driven into the sockets as far as was considered prudent, the ends projecting beyond the sockets were cut off, and a few small iron wedges were then driven into the wood for the purpose of giving a final tightening. These joints were found to be a great improvement on the previous system of flanges ; but as the wooden wedges became saturated with water, they expanded, and frequently burst their sockets. This led to the abandonment of the system of jointing pipes with wooden wedges, and to the adoption of the plan of filling the back part of the socket with yarn tightly rammed in, and then running the remainder of the socket full of molten lead, which on cooling was caulked up, and so made a tight and permanent joint capable of withstanding the full pressure to which the pipe might be subject, and, at the same time, of allowing for expansion and contraction without leakage.

This method, for the first time, gave those responsible for the distribution of water under pressure the advantage of having at command continuous distributing tubes of any length, and practically water-tight under any ordinary pressures.

The lead joint, as above described, with variations only for reducing the weight of lead used, or for adding to its security against being blown out by back pressure, has remained a permanent institution, a bar of lead being occasionally substituted for the molten metal.

In some cases, the old-fashioned method of jointing the wooden pipes has been imitated in their cast-iron successors by turning a conical end to the spigot, and boring the socket, so that, when fitted together, the pipes practically joint themselves without any other stopping.

With the introduction of cast-iron pipes, and greater pressure, the system of intermittent supply became more completely developed and established.

Under the intermittent system, the supply of water was not constantly laid on, as is now almost universally the case. The arrangement was to turn on the water from the principal main into the subsidiary distribution pipe, in any particular street, for an hour or an hour and a half a day; during which time all the people in that street had to draw and store a sufficient supply for the remainder of the twenty-four hours.

This system, with which the public were long content, ultimately fell into disfavour. Its inconveniences were great; the water was, as stated, only turned on for a very short time; the system necessitated the employment of a large number of turncocks, whose sole business it was to go round the districts to turn the water on and off. The intermittent system was also injurious on sanitary grounds, as it frequently happened that the vessels in which the water was stored were exceedingly foul, in consequence of putrefying sediment left in them from previous supplies, and the stored water itself was apt to become impregnated with poisonous gases rising through the waste or overflow pipes of the cisterns which were connected with the sewers.

The sanitary defects thus inherent in the intermittent system were the fruitful source of disease and death, and early engaged the attention of the Board of Health presided over by the late Earl of Carlisle, and of which Mr. Edwin Chadwick, C.B., was the earnest and indefatigable secretary. After much inquiry the Board came to the conclusion that these evils could be remedied by the adoption of the constant supply system, which had been introduced at Nottingham by Mr. Thomas Hawksley, past president of the Institution of Civil Engineers, and was in successful operation there on a large scale.

Under the " constant " system, the supply is kept on the whole twenty-four hours, so that anyone, at any time of the day or night, by simply turning a tap in the house, can obtain a supply direct from the main without the intervention of any intermediate storage vessel.

When the proposition for affording a supply on the constant system was first broached by the Board of Health, it was met by a storm of opposition, some engineering advocates of the old system going so far as to allege that it would be a sheer impossibility to carry out the constant system, on account of the uncontrollable waste that would result from having the water always " on," and because, as there was no guarantee that everybody would not be drawing water at the same time, the main pipes would in consequence have to be of enormous magnitude compared with those necessary under the intermittent system, under which system it was alleged the supply could be more judiciously and economically manipulated.

The controversy on this question raged with great vigour from 1845 to 1850. About that time Sir Robert Rawlinson, C.B., having occasion to visit Wolverhampton in connection with a local inquiry under the Board of Health, asked the writer, who had then recently converted the supply of that town from the intermittent to the constant system, and who at the moment had the means of doing so with great accuracy, to institute some experiments with a view to ascertain what, under the constant system, was the actual rate of consumption at each hour of the day. As the result of these experiments, the writer found that, so far from all the people drawing from the mains at the same time, the highest rate of consumption was only about two-and-a-half times the total daily supply ; that is to say, that the main and distribution pipes under the constant system should be of a capacity sufficient to supply two-and-a-half times the ordinary daily consumption. Now, as under the intermittent system it was the practice to make the mains and distribution pipes of sufficient capacity to supply four times the ordinary daily consumption, these experiments proved that, so far from larger mains being required under the constant system, they might actually be made of smaller capacity than those required for the intermittent system. It was also shown that, with proper fittings in the houses, the consumption of water under the constant supply system was actually less than that under the intermittent system.

These facts being reported by the Board of Health, and afterwards given in evidence by the writer before a Committee presided over by the late Sir James Graham, and confirmed also by similar results in other cases, brought the controversy to a close in favour of the constant supply system, which is now almost universally adopted, and under which 263,904 out of the 671,888 houses in the London district are now supplied, as stated in the able and interesting report for May, 1884, of Colonel Sir Francis Bolton, Official Water Examiner under the Metropolis Water Act, 1871.

The introduction of the system of constant supply brought about other advantageous changes in the method of distribution. Under the intermittent system the water lay stagnant in the distribution pipes for at least twenty-two out of the twenty-four hours each day, and before the introduction of filter beds these pipes were practically small settling reservoirs in which the sediment accumulated, and which sediment, when the water was turned on, was driven with the first rush, in a semi-putrescent state, into the household storage receptacles.

Under the intermittent system, but little attention was paid to fittings in the houses, as neither those supplying the water nor those receiving it troubled themselves much about waste, which in each case did not last more than an hour or an hour and a half each day. Hence taps, ball-cocks, house supply pipes and other internal fittings were old-fashioned and defective almost beyond description.

With the advent of the constant system, new descriptions of fittings were introduced to prevent waste, and to meet the requirements of the greater pressures at which the water then began to be delivered.

It may be safely affirmed that the constant system has brought about an extraordinary change for the better in all domestic water fittings; those now in general use displaying an amount of skill, ingenuity, and good workmanship far superior to anything ever before known.

Under the intermittent system the distribution pipe necessarily had a "dead end" in each street, because, the water requiring to be daily turned on or shut off, the pipe could only be connected at *one* end with the feeding main, leaving the other end isolated or "dead." The water near these dead ends became very foul from stagnation, and consequently the dead end required to be frequently washed out. This was effected by drawing a wooden plug fixed in a branch at the end of the distributing main. When this plug was drawn, it was not at all uncommon to see the water spouting out from it tinted with all the colours of the rainbow, from dark purple to the lighter tints, and emitting a most offensive odour, for when the water was shut off, it frequently happened that the distributing pipe was drained by a discharge at some low-lying part of it, and it then became filled with an atmosphere drawn through ground full of gas reek.

Under the constant system these evils, including those resulting from dead ends, are done away with; the distributing pipes being now constantly under pressure, no gas reek or other impurities can enter them, and being connected at each end of the street with the adjoining mains, there is a constant circulation throughout the whole system, whereby stagnation is prevented, as the water is always on the move towards the point of greatest consumption.

Very great improvements have also been made under the constant system, in the construction of the sluice valves for shutting off the water for repairs at any particular point. Under the intermittent system, the sluice valves were only made to shut against the pressure from *one* side, whilst they are now universally made to shut against the pressure coming from either side or in any direction. These valves, which are called "double faced," are the invention of Mr. James Nasmyth, so well known in connection with the steam hammer. The writer, then an articled pupil to the late Mr. Wicksteed, engineer to the East London Waterworks, had the privilege of assisting Mr. Nasmyth in preparing the first rough drawing of these "double-faced" sluice valves; and he well remembers the instantaneous rapidity with which that great mechanician not only grasped the point to be attained, but within an hour had so completely solved the difficulty to be overcome, that whilst alterations have been made in minor details, no practical improvement has been effected in that first design of his.

The method of connecting the house services with the main pipes has also undergone a great improvement. In early times the connection was made by driving a brass ferrule into a hole chipped or drilled through the main pipe. These ferrules were apt to be dislodged, and frequently blew out, and the fixing of them obliged the water to be shut off from the whole street during this occasionally tedious operation. These connections are now made by screw threaded ferrules, tapped securely into the pipe by an instrument which obviates the necessity for any stoppage of the supply to other houses whilst the operation is being performed.

The arrangements also for the supply of water for fire extinction have been very greatly improved since the introduction of the constant supply system. In former times, in the event of a fire, the first thing was to find the turncock to turn the water into the main. This done, the old wooden plug had to be knocked out, often a work of time and difficulty ; and then until all the empty tubs and tanks were filled up in the street there was practically very little pressure at the plug, and the supply was consequently scanty for some time. Thus most precious moments were lost. Now, on the contrary, the fireman goes to the nearest hydrant, inserts his standpipe, turns on the water from the constantly charged main pipe, and in a much less time than it previously took to call the turncock, he has a stream of water pouring into or over the burning building at the rate of 200 or 300 gallons a minute, and under a pressure sufficient to knock a strong man down at a distace of fifty yards from the nozzle of the fire-hose, and that without the intervention of any fire-engine.

Another little machine which has proved itself to be of great value in connection with constant supply, is the "Waste Water Detector," invented by Mr. Deacon, the engineer to the Liverpool Corporation Waterworks. This machine indicates and registers the flow of water passing through any particular pipe at any moment of time, and by its agency all undue waste and leakage are easily detected and traced. Thus the modern appliances in connection with distribution, if properly used and directed, are now nearly all that can be desired.

Except in very special cases, the writer is not an advocate for the "Dual System," that is a system under which two classes of water are introduced into a town ; the one for dietetic purposes, and the other for washing, street-watering, sewer-flushing, fire-extinguishing purposes, &c. The dual system necessarily involves the laying of a duplicate set of mains, and the fixing of a duplicate set of house fittings, with all the attendant annoyance and expense.

There may be cases where the circumstances are so peculiar as to make the dual system a necessity, and then the difficulty must be faced; but generally it will be found cheaper and better to manipulate the supply so as to make sure that none but water of a high class shall ever enter the mains, and so as to effect the whole work of distribution by one set of pipes and fittings.

WATER SUPPLY FOR FIRE EXTINCTION.

By J. H. GREATHEAD, M.Inst.C.E.

WHEN it is considered how vast is the havoc wrought by fire every year, and that we depend upon a supply of water, in all cases, to prevent much greater ravages, the importance of this subject will be at once recognised.

In London alone, it has been calculated on reliable data that the destruction of property in 1882 amounted to at least 2¼ millions sterling, and last year it was probably more; and it has been stated by a very good authority, Mr. Edward Atkinson, of the Boston Manufacturers' Mutual Insurance Company, that the losses by fire in the United States and Canada in the five years ending January 1st, 1879, amounted to 82½ millions sterling, while the cost of insurance companies and fire departments in the same period amounted to 55 millions more, or together to an average of 27 millions sterling per annum.

It is difficult for the mind to grasp such figures; the last, however, is about equal to the whole rateable annual value of the metropolis.

If such losses as these were inevitable, it would be of little profit to refer to them, but it is because I believe them to be to a large extent preventible, that I have ventured to bring the subject of water supply for fire extinction before you.

In the remarks which I am about to make, I purpose to refer largely to the case of this metropolis as being likely to add additional interest to the general subject, and because the reasoning which applies to this will apply in a greater or less degree to all other similar cases.

It may be useful at once to define what are the requirements necessary to be fulfilled in a water supply for fire extinction purposes.

In order to reduce, as far as possible, the destruction of life and property by fire, the fire extinguishing service should have water—

(1.) In copious supply.
(2.) In close proximity to the property.
(3.) Easily accessible.
(4.) Having sufficient and reliable pressure.

In nearly all cities the water supply has been introduced and distributed without reference to the fulfilment of these conditions. The quantity of water required for the extinction of fires is so infinitesimal as compared with the quantity required for all other purposes, that, except where the conditions have been naturally favourable, the water service is devoid of some at least of the qualities necessary to fit it for fire purposes. The result, in such cases, has been that mechanical contrivances have had to be provided to make good whatever deficiencies existed in the supplies, and dwellers in cities have become familiar with fire-plugs and fire-engines.

There are, however, some cities in this country where, the conditions having been favourable, the authorities having control of the water supplies have availed themselves wisely of Nature's gifts.

The most notable instances are those of Glasgow, Dublin, Liverpool, and Manchester. In all these cases the water supply is almost entirely by gravitation, and the result is that over the greater and most important parts of the cities there is a good pressure and a copious supply of water, which has been made easily accessible by the introduction of numerous hydrants in close proximity. Here, then, we have, as nearly as may be, in four of the most important cities of the United Kingdom, a fulfilment of the necessary conditions of water supply for fire extinction.

An ordinary hydrant may be shortly described as a stop-cock on a water-pipe or main, to which hose may be attached for fire extinction, or other purposes. If for fire extinction, without the intervention of a fire-engine, the hose will, at its other end, be provided with a branch and nozzle. Upon opening the stop-cock, the water from the main, or pipe, will issue from the nozzle as a jet. The height of the jet will depend upon the pressure in the main, the quantity of water available, the length of hose employed, and the size and shape of the nozzle.

A fire-plug is a wooden plug driven tightly into a socket or opening in a water-pipe under the road. When water is required for fire extinction the plug is withdrawn, and the water issues from the opening, either into the street, where it is usually received by a portable tank, or into a stand-pipe inserted in place of a plug. It is obvious that plugs cannot be used where the supply is constant with a good pressure, and they have not been placed upon the constantly charged mains (the best existing supply for fire extinction) in the metropolis. Several forms of hydrants, and a fire-plug and stand-pipe, may be seen in the Water Companies' Pavilion in the Exhibition.

In order to obtain a good jet from a hydrant, it is necessary that the pressure of water at the hydrant, while flowing, should be about 65 lbs. per square inch. This will provide for overcoming the friction of the water in passing through an average length of hose, and will give a jet about 80 feet high from an inch nozzle. From the elaborate reports of the chief officer of the Dublin Fire Brigade, which he has kindly furnished to me, it appears that all the fires in Dublin, except those extinguished by small hand pumps, are put out by jets direct from the hydrants, and that the prevailing pressure is about 60 lbs. per square inch.

So much has been written and said about hydrants, and the advantages to be derived from their use, during the last twenty years, that it is hardly necessary for me to discuss their merits as compared with fire-plugs. It is generally conceded that in all cases, whatever the water supply may be, whether constant or intermittent, high pressure or low, hydrants are superior to plugs as a means of letting the water out of the pipes. But it has been contended that so long as it is merely a question as between hydrants and plugs, the advantages of the former over the latter are not sufficiently great to justify any large expenditure upon them. When, however, the question becomes one as between hydrants and fire-engines, a wider view becomes necessary. Hydrants with a constant and copious supply, and good pressure of water, are recognised as being incomparably better agents for extinguishing fires than fire-engines, and the result of the introduction of hydrants into Manchester may be given in illustration. Mr. Bateman, the eminent engineer of the Manchester Waterworks, has stated publicly on more than one occasion, that the introduction of hydrants with a good pressure of water has resulted in a reduction of the losses from fire in Manchester to a small fraction (viz., one-seventh) of what they were before the introduction of the hydrants. And according to the report of Captain Tozer, the superintendent of the Manchester Fire Brigade, the amount of property destroyed has only averaged 4·3 per cent. of that at risk during the last ten years, while it will be seen presently that in places having no efficient hydrant services the losses are many times greater.

In Liverpool, the fire brigade is a branch of the police. The water supply is mainly by gravitation from reservoirs (from 400 to 600 feet above the low parts of the town), and there are numerous hydrants. There are 3 steam and 14 manual fire-engines. The population in 1881 was 548,650, and the area is 8¼ square miles. Of the 180 firemen, 170 do regular police duty. The average annual cost of the brigade for the three years 1880, 1881, and 1882, was £5325, or £9 14*s.* per 1000 of the population. The average annual number of fires in the same period was 219, but the loss by fire was not ascertained.

In Glasgow, there is a good supply of water by gravitation; there are about 5000 hydrants, and the majority of the fires are extinguished direct from the mains. There are 3 steam and 17 manual fire-engines. The 66 officers and firemen are supplemented by an auxiliary force of 52 policemen. The area of the city is 9½ square miles, and the population in 1881 was 510,816. The cost of the brigade to the ratepayers in 1882 was £5266, or £10 6*s.* per 1000 inhabitants; while the annual average loss from fire in the same period was £110,000, or about £215 per 1000 of the population.

In Manchester, the supply is also by gravitation from reservoirs at a considerable elevation (200 feet to 600 feet above the Exchange), and there is a constant high pressure supply. There are about 17,000 hydrants in the city and suburbs. Two steam and 5 manual fire-engines are retained, but are seldom used. The population in 1881 was 341,500. The area of the city is 6¾ square miles, but the fire brigade extend their operations beyond the city. There are sixteen stations, and the average annual cost to the ratepayers for the fire brigade during the three years 1880, 1881, and 1882, was £3547, or equal to £10 8*s.* per 1000 of the population. The average estimated annual value of property destroyed in those three years was about £80,000, or about £235 per 1000 of the population.

In Dublin, the supply of water is again by gravitation, and the pressure varies from about 40 lbs. to 80 lbs., being generally 60 lbs. when the water is flowing through the hydrants. There are numerous hydrants, and though there are 2 steam and 3 manual engines, they do not appear to have been used in the three years (1880–1882), within the city. The brigade consists of 32 officers and men. The population in 1881 was 249,602, and the area of the city is

6 square miles, but the operations of the brigade are not confined to that area. The average annual cost of the brigade for expenses and wages for the three years in question was £3286, or about £13 3*s.* per 1000 of the population. The estimated value of property destroyed averaged £31,144 per annum, or about £125 per 1000 of the population.

In Birmingham, the whole of the water supply is pumped, therein differing from the cases already referred to; but a system of fire hydrants has been recently introduced. The population (average of 1882 and 1883) is 411,690, and the area 13 square miles. The fire brigade consists of 27 officers and men, and there are 2 stations and 8 police stations, with apparatus. One steam and 5 manual fires-engines are retained, none of which were used for fire extinction in 1882, and engines were used twice only in 1883. The total water supply is 11½ million gallons daily, with a pressure of 40 lbs. to 60 lbs. per square inch. The average annual cost of the fire brigade to the ratepayers during 1882 and 1883 was £3250, or £7 18s. per 1000 of the population, while the average annual loss in the two years was £10,931, or £26 11*s.* 8*d.* per 1000 of the population, and this loss was equivalent to 3 per cent. only of the value of the property "at risk."

Having now described the operations, and their results in cities having efficient hydrant services, I propose to direct attention to some of the more important of the cities having no such services, and more particularly to New York and London.

In New York, the water supply is very copious, but it has not sufficient pressure for fire purposes without the intervention of fire engines. Hydrants have, to some extent, been introduced, and it is stated with benefit, as they permit more speedy access to, and prevent waste of, the water. The total supply is, according to the report of the fire department, about 100 million gallons daily; the population in 1880 was 1,206,300, and in 1881 probably 1,240,000. The area served by the fire brigade is about 39 square miles. In 1882, there were 50 engine company and 19 hook-and-ladder company stations, besides look-outs, fuel depôts, and store houses. There were 57 steam fire-engines but no manuals In the period 1880-82 the average force was 939 officers and men, and the average annual expenditure was £288,190, or £230 8*s.* per 1000 of the population. In the same period the average annual fire losses were £880,000, or about £710 per 1000 of the population. The quantity of water used by the fire-engines was about 40,000,000 gallons annually in the period 1880-2, or about 1-900th part of the total supply.

In London, the whole of the water supply is pumped, and the average pressure is quite inadequate for fire extinction without the intervention of fire-engines. A large number of observations were made all over the metropolitan area by the Board of Works, in 1876, and it was found that the average pressure was only about 30 lbs. per square inch, when there was no extraordinary draught on the pipes, such as that required for fire extinction. It is not surprising that this should be so. The pressure given by the water companies is that required by statute, or, otherwise, by the customers of the companies, and even if they desired to do so it is doubtful whether, in the words of the Select Committee of 1876-7, the companies would be "justified by their constitution in incurring expenditure for fire purposes," for which purposes alone it would be necessary for them to increase their pressure.

The quantity of water delivered for all purposes is sufficient to meet the demands for fire extinction. There are, according to Captain Shaw's reports, very few cases of short supply, and constant supply is being gradually extended voluntarily by the water companies. Hydrants have been put down by the Corporation throughout the City, and connected directly by branches with the constantly charged mains of the New River Company, and they have on several occasions been found useful, though the pressure is not such as to admit of fire-engines being dispensed with in all cases. A few hydrants have also been recently introduced by the Metropolitan Board of Works to other parts of the metropolis.

In the matter of pressure, however, as already stated, the general metropolitan water supply is undeniably deficient. There is a copious supply of water, contiguous to the property to be protected, but it cannot be brought to bear upon a fire without the intervention of fire-engines.

The population of the metropolis, in 1881, was 3,814,571, and the Metropolitan Board of Works area is about 121 square miles, including the City's one square mile. There are 55 land fire-stations, 12 street, 127 fire-escape, and 4 floating stations; and the brigade consists of 588 officers and men. The annual average cost of the fire brigade for the three years 1880–2, was £99,880, or £56 4*s*. per 1000 of the population. It is somewhat difficult to arrive at the value of the property destroyed by fire in the metropolis, but a calculation based upon the contributions of the insurance companies to the support of the fire brigade, and upon evidence given by Captain Shaw and others before the Select Committee on the Fire Brigade, in 1877, would make it appear that in 1882 the value of insured and uninsured property destroyed by fire was probably considerably in excess of 2¼ millions sterling, or about £588 per 1000 of the population. As compared with the efficiently hydranted places already referred to, it will be seen that the cost of the fire-extinguishing service, and the fire losses are very high in London. This will be made very apparent upon an inspection of the appended Table A (page 102), which gives, in addition to the cost of the fire services and fire losses in the several places referred to, a statement of what the cost and losses would be in the metropolis, were the rates of cost and loss the same as in the other places.

It will be asked why the metropolis should have been allowed to remain year after year subject to the preventible drain of wealth indicated by these figures. The reply is that, the past and existing state of things have not been submitted to in ignorance or willingly, but the difficulties surrounding the subject in the metropolis have been practically insurmountable.

More than twenty years ago, the Select Committee on Fires in the Metropolis directed attention to the extraordinary facilities for extinguishing fires then existing in Liverpool, Manchester, and Glasgow, and to the efficiency and small cost of the fire services in those places; and more recently, in 1876–7, the Select Committee on the Metropolitan Fire Brigade, having heard evidence as to the advantages of the hydrant systems referred to, recommended that hydrants should be put down in the metropolis at once wherever a constant supply was given, and that the water supply should be improved so as to give everywhere constant service and increased pressure. But it was found that to comply with these recommendations a permanent expenditure of £337,000 per annum beyond the cost of the fire brigade would be involved. Of this annual sum about £150,000 represented the increased cost of pumping alone; and since the quantity of water required for fire purposes is infinitesimal as compared with the quantity supplied for all other purposes, it is obvious that this expenditure of power, if the whole had to be pumped to the requisite height, would be out of proportion to the result obtained. I have made a calculation, based upon the relative quantities, and upon the evidence given before the Committee, from which it appears that for the purpose of discharging water through a hydrant upon a fire in this way, about 170 horse-power would be required for every gallon of water thrown. And there would be the attendant disadvantages that all the house fittings would have to be altered and strengthened, and the mains and pipes would have to be taken up, and relaid of greater size and strength, and at enormous inconvenience to the householders and the traffic in the streets; and the pressure would, in the greater part of the metropolitan area, be inconveniently great. This proposal also involved the great disadvantage that it could not be carried out until the water companies should have been ranged under one control.

As long ago as 1862, the late Mr. James Easton, who held the view that no satisfactory supply of water for fire extinction with constant high pressure could be secured in connection with the ordinary domestic supply, proposed to lay down a completely new set of mains to be used exclusively for fire purposes, but the cost would have been enormous. His estimate was £72,000 per square mile, and his proposal only extended to forty square miles of the metropolis. This area alone would have involved an annual cost for interest and working expenses of £150,000. A somewhat similar proposal was put forward by the Metropolitan Board of Works, on the advice of Sir J. Bazalgette, Sir F. Bramwell, and Mr. Edward Easton, in 1877, but with the addition that the water was to be taken from the chalk formation at about fifteen or twenty miles from the centre of London, instead of from the water companies' mains as was proposed by Mr. Easton, and that the supply was to be used for potable and culinary purposes after being pumped to the greatest attainable elevation in order that it might have sufficient pressure for fire extinction purposes. It was estimated that the introduction of such a system of hydrants would have resulted in an annual saving of £60,000 in the existing expenses of the fire brigade. This scheme, involving a dual supply to every house, was taken to Parliament, but was withdrawn ; and in their annual report of 1878, the Board said that they "came to the conclusion, in view of the disfavour with which the scheme appeared to be regarded by most of the local authorities of the metropolis and others, not to bring it before Parliament again in the following session." Looked at purely from a fire extinction point of view there is one great objection to all the proposals that have been hitherto made, viz., that owing to the great variations of level in the metropolis, there would, in many localities, be insufficient pressure, while in others the pressure would be excessive.

In any water supply for fire purposes, it is certainly desirable that the pressure, in addition to being sufficient, should also be moderately uniform in the hose, whatever may be the elevation of the locality. This uniformity is practically obtained at present by the use of fire-engines, but with the great drawback that the power requisite for giving the pressure is not available on the instant that the occasion for its use is discovered. The diagram B (on the wall) illustrates among other things the result of the vigorous efforts made by the fire brigade to reduce this evil to a minimum. It shows that since the year 1870, when Captain Shaw first began to publish the distances travelled by his engines—the distances run have increased from 11 miles per fire in 1870 to 34¼ miles in 1882. The number of journeys made has increased from 8000 to 29,000, and the total distance run from 22,000 miles to 66,000 miles in the year.

According to the evidence given before Sir H. Selwin Ibbetson's Committee in 1877, the fire-engines were then used for pumping at about one-fifth of the fires only. If that was still the case in 1882, then it follows that for each time the engines were used for pumping upon a fire they must have run on an average 172 miles.

When it is considered under what unfavourable conditions, and how uselessly the journeys are often made, some idea may be formed of the superiority of a system of hydrants where the power as well as the water is always on the spot ready for instant application. The same diagram illustrates also another feature of the fire brigade service, viz., the growth of its cost from the commencement of the old fire-engine establishment in 1833. It will be seen that the growth has been, and is very rapid as compared with the growth of the population. In the first year of the Metropolitan Board of Works' administration of this service, the cost of the brigade was under £41,000; in 1882 it was £106,552, or an increase in the period of sixteen years of 160 per cent., while the population increased only 28 per cent., and the number of fires 44 per cent. In the year 1883, the cost had further increased to over £115,000. It must not be supposed for a moment that this increase is to be regarded as unnecessary under existing conditions.

The cost of the London Fire Brigade is, thanks to Captain Shaw's admirable organisation, still small as compared with some other unhydranted cities. In New York, as already stated, the cost is very much greater for less than a third the population and area. There the average annual cost for the three years, 1880–3, was over £288,000, and it appears to be growing almost as rapidly as that of London, though on the other hand the population there is growing more rapidly. Paris, also another practically unhydranted city with half the population, spends proportionately more than London for fire extinction.

In Paris, the water supply is partly pumped, and partly acts by gravitation. Street hydrants have, to some extent, been introduced. In certain cases, where the pressure is sufficient, they are used without the intervention of fire-engines, but the water supply is not such as to admit of this being done generally. It is intended, however, to increase the number of hydrants to 8000, and ultimately to make them universal, and to dispense with fire-engines. The total daily supply of water is about 82 million gallons. The population is 2,269,000, and the area 29 square miles. The fire-brigade, numbering 1743 officers and men, is an armed force lent for this special service by the Minister of War, and is not called out for purposes of war. There are 11 barracks, 10 steam fire-stations, and 80 small stations in addition to 40 look-outs; there are also 12 steam and 80 manual fire-engines. The average annual cost of the fire extinguishing service is £86,600 for the two years, 1883 and 1884, or about £38 3*s.* per 1000 of the population, but this cost does not include the rent and repairs of the barracks, quarters, &c., which belong to the Prefecture of the Seine. The estimated annual average losses for the three years, 1880, 1881, and 1882, were £431,300, or about £122 10*s.* per 1000 of the population.

The question of the cost of fire extinction, again, is not the sole consideration; behind that there is the question of fire loss, or the destruction of property by fire, and the loss of life. Putting aside the last and highest question as being one not altogether dependent upon the extinguishing service, I propose now to direct attention to the question of fire losses as affected by the absence or presence of efficient hydrant services.

In describing the hydranted cities, I have already given the fire losses in four of them, viz., Glasgow, Manchester, Dublin and Birmingham, in accordance with the published estimates, and I have shown that the losses are—in Glasgow £215, in Manchester £234, in Dublin £125, and in Birmingham £26 11*s*. per 1000 of the population. In the case of New York, the losses are published in detail, and amount to about £710 per 1000 of the population, as compared with £588, the loss in the metropolis, as estimated by myself.

The Table A (on p. 202), has been prepared in accordance with the facts I have stated; but in order to give the figures a practical bearing in the case of the metropolis, I have added two columns which give the costs and losses of a place having the population of London, at the same rates as each of the places considered. It will be seen that the annual cost of extinction by hydrants, if it were at the same rate as Liverpool, Glasgow, Manchester, and Birmingham, would be from £30,000 to £40,000; and at the same rate as Dublin, £50,000; while if it were at the same rate as New York, the cost would be £886,000, instead of £99,880, the average annual cost in London in the years 1880–2.

The diagram H (shown on the wall) has been prepared from Captain Shaw's table already referred to, and it seems to place the value of efficient hydranting in a very striking light. From the table referred to have been compiled the figures, giving the cost of the fire brigades in a number of important towns at the date of the compilation of the table (1877). The cost in the hydranted cities, viz., Glasgow, Liverpool, Manchester, and Dublin, has been shown in red. The blue line shows the cost in a number of American cities. Paris and London, having populations respectively twice and over threefold as great as New York, are not shown, but from the table and the remarks upon it, it will be gathered that in both those cases the cost would be far above the rates shown by the red colour, which has been extended to embrace a place of the size of New York.

In the foregoing remarks, I have simply taken population as the basis of comparison between the several places. I do not pretend to say that there are not exceptional considerations apart from the question of water supply, such as areas, character and proximity of buildings, habits of people, and so on, which would, and no doubt do, materially influence results, but the distinction between the hydranted and unhydranted places is so broad and marked where the places are of such different characters on the one hand as Glasgow, Liverpool, Manchester, and Dublin, and on the other hand as London, New York, Paris, and Birmingham, that it must appear to all that the absence or presence of efficient hydranting far outweighs any other consideration.

It now remains for me simply to add that, having for some years devoted much study to the subject, I believe that, notwithstanding all the difficulties, only the chief of which have been adverted to here, there are methods—or perhaps I ought rather to say there is a method—by which such cities as London, New York, and Paris may be efficiently hydranted at a comparatively small cost, and practically with very trifling inconvenience, which method I have already described in papers read at the last meeting of the British Association, and before the Institution of Mechanical Engineers.

It is, however, obviously impossible, within the limits of a single paper, to discuss the whole question. I therefore content myself on this occasion by advancing the proposition that efficient hydrants form, as far as our experience goes, the only effective weapon with which fire brigades can successfully cope with fires.

APPENDIX.

Table A.—Annual Cost of Fire Extinction, and Annual Amount of Fire Losses, in some Hydranted and Unhydranted Cities.

Average of 3 years, 1880, 1881, 1882.

	Population, 1881.	Area Square Miles.	Cost of Fire Brigade.	Cost of Fire Brigade per 1000 Inhabitants.		Cost of Fire Brigade of Metropolis at same rate.	Loss.—Property destroyed by Fire.	Loss.—Property destroyed by Fire per 1000 Inhabitants.		Loss of Property in Metropolis at same rate.
* Hydranted.		£	£	£	s.	£	£	£	s.	£
Liverpool	548,649	8·28	5,325	9	14	37,000	—	—		—
Glasgow	510,816	9·55	5,266	10	6	39,290	110,000	215	7	821,542
Manchester	341,508	6·7	3,547	10	8	39,670	80,180	234	16	895,644
†Dublin.	249,602	6·0	3,286	13	3	50,200	31,144	124	16	476,050
Birmingham, 1882–3 . .	411,689	13·15	3,250	7	18	30,115	10,931	26	11	101,287
* Unhydranted.										
London	3,814,571	121	99,880	26	4	99,880	2,242,400	587	19	2,242,400
New York	1,240,000	39	288,190	232	8	886,490	880,000	709	14	2,707,150
‡Paris, 1883–4	1,269,023	39	§86,600	§ 38	3	145,500	‖431,300	‖192	10	734,300

* The term "hydranted" and "unhydranted" indicate the presence or absence in each place of a complete system of hydrants which are used for fire extinction without the intervention of fire engines.

† The cost of the Fire Brigade has been reduced from £3616 in 1880, to £3053 in 1882.

‡ A large number of fire hydrants have been put down, and some have been used without the intervention of fire engines, but the average pressure is not such as to admit of this being generally done.

§ Average of 1883 and 1884, exclusive of rent and repair of quarters, barracks, &c.

‖ Average of 1880, 1881, and 1882.

REMARKS ON THE DISTRIBUTION OF WATER.

By JOSEPH QUICK, Jun., M.Inst.C.E.

Next to the importance of securing a supply of water of good quality for the requirements of a city or town, is that of its distribution, for however superabundant the source may appear to be, the advantages to be derived from its use, and the number of those whom it may benefit, must necessarily be in a great measure dependent upon the way in which it is distributed.

The author does not propose to enter here into the question as to the works necessary to bring an ample supply of water into a city or district, but assumes, for present purposes, that such works have been well executed, and that properly proportioned distributory pipes have been laid, and service reservoirs or other means provided for affording a supply of water at high pressure throughout the district to be supplied.

The history of the water supply in England is eminently instructive, as showing not only the various phases through which it has passed as refinement and sanitation have advanced; but also as proving the absolute necessity of proper control being exercised with regard to its distribution.

Not to weary my hearers with unnecessary detail on this point, it may suffice to refer to the discussions which have taken place during past times, as to the relative merits and practicability of the systems known as "intermittent" and "constant" supply respectively.

It is within the author's recollection when it was the exception, instead of being, as it is to-day, the rule for towns in England to enjoy the advantages of constant supply; but up to this moment there are many instances, notably in the metropolis itself, where the intermittent supply still, either wholly or partially, prevails. It is hardly necessary to explain that by "constant" as opposed to "intermittent" supply, the author refers to the difference between the mains and house-service pipes being always charged with water, so that it can be drawn off direct from the main at any hour of the day or night by the consumer, instead of, as on the intermittent system, the supply being only turned on for a limited time, varying from half-an-hour to two hours per day, during which time any receptacles, cisterns, &c., provided by the consumer, have to be filled, and suffice for use until the operation of refilling them is repeated on the next and subsequent days.

Of the advantages of the constant supply for domestic purposes, independent of its being immediately in case of fire, it is almost needless to speak, especially for the poorer class of houses in cities and towns, whose only receptacle frequently consists of a dilapidated and uncovered water-butt, the water in which is exposed to all the evils of contamination from the atmosphere and other sources. No one who has travelled by the railway in any part of London can have failed to observe, in the crowded districts traversed, innumerable instances of this kind, which are amongst the most prolific causes of disease amongst the lower classes of the population. It is, indeed, little short of a crime on the part of those responsible for this order of things, that human beings should be compelled to obtain their drinking water from such contaminated receptacles; and it is doubly wrong that, after the suppliers of water have done all in their power to improve, by filtration and other means, the quality of the water, and to prevent its pollution at its source, it should, after delivery to the consumers, be allowed to thus become deteriorated in quality, and a source of danger to health.

One of the great advantages offered by the constant supply system, as already stated, is to abolish the necessity for any of these miserable receptacles; and it is difficult to imagine a greater blessing, or one more conducive to sanitation, than the introduction in their place of water direct from the water mains to the consumer's tap.

Although the author has alluded thus prominently to the evils attendant upon the butts so frequently found in the dwellings of the poorer classes, it is not to be supposed that the evil is limited to them ; on the contrary, in some houses of the best class, where cisterns are employed, the same evils, although in a minor degree, prevail. The author feels justified in asserting, as the result of upwards of twenty years' day-to-day experience in connection with the water supply of London, that the periodical cleansing of cisterns, from which it is impossible to exclude a certain amount of dust and dirt, even in first-class houses, is the exception rather than the rule, and that, in a large percentage even of the better class of dwellings, a further serious evil arises in consequence of the overflow pipes from such cisterns communicating direct with the drains, without the intervention of a proper trap, thus allowing the foul gases from the drains to communicate with, and thereby contaminate, the water in the cistern.

The obvious question arises, under the above circumstances, why the constant supply is not universal throughout the length and breadth of the land ? This is a question which has puzzled many a Parliamentary Committee, and although it has made great progress, it is still but imperfectly understood. The difficulty has usually been ascribed to either the inability or unwillingness of the water authorities to adopt it, on the score of expense ; and this has frequently been brought forward as one of the reasons in favour of the transfer of the management of the water supply from private companies to a public body ; but, on closer investigation, and to the few professionally familiar with the subject, it is apparent that the real difficulty is not to be attributed to this cause, which would have been almost equally difficult to cope with had the water supply been under public instead of private control.

The real difficulty in effecting the change of system consists in having to graft it on to the old state of things, which involves the re-arrangement of the various pipes, taps, closet apparatus, &c., in the houses in such a manner as to prepare them to receive the constant supply, and at the same time prevent waste of water.

It was a long time before the absolute necessity of stringent regulations to prevent waste was understood or appreciated, except by those immediately conversant with the practical everyday working of waterworks ; but eventually it became evident, even to those most clamorous for the new system, that the enforcement of such regulations was absolutely necessary to ensure its successful working. When once this was officially recognised and admitted by Parliament to be indispensable, the necessary powers were granted, both to the metropolis and in the provinces, of which the latter afford some instances of a highly successful result, both in the changing of the system from intermittent to constant supply at the same time, and the effecting of a large reduction in the quantity of water required, after providing an ample supply for all purposes to the inhabitants.

The author may mention as an example, the town of Portsmouth and surrounding districts of Portsea and Southsea, where the Water Company supply a population of 140,000, occupying 27,545 houses, of which a large number are of a very small class. The company was established in 1857, and until the year 1876 the supply was intermittent throughout the borough ; but in 1873 an Act of Parliament was obtained, under the advice of the author's firm, entitling them to make the necessary regulations to prevent waste, and these regulations were sanctioned by the arbitrator appointed, Dr. Pole, F.R.S., in April, 1876.

It will be seen by these regulations that while ample power is given to the company to require waste-preventing apparatus to be used, the company are restricted from requiring alterations of fittings until the existence of such waste is actually proved ; the effect of this has been to necessitate more frequent inspection, and to some extent to cause delay in introducing the new system ; nevertheless, the activity of the company's resident engineer, Mr. H. Smith, was such that in March, 1880, or within four years from the official approval of the regulations, the constant supply was given to the whole borough, and has continued without interruption to the present time. Owing, however, to the very extensive supplies for trade and public purposes, and for the use of her Majesty's Dockyard given by the company, the actual supply for all purposes still amounts to 30 gallons per head per day ; but there is every reason to believe that by the means the company are still taking to detect cases of waste, as hereafter described, the consumption will be still further considerably reduced.

Probably the extent to which waste of water exists is best tested by asking the question—"What is the quantity really required per head per diem," and comparing it with the quantity actually supplied to any particular town or district ; the answer to the former will of course depend upon local circumstances ; for instance, in a manufacturing town, or one where unusually large quantities of water are required, for Government establishments, breweries, or trades requiring considerable supplies, the consumption per head per day will be much greater than in a purely residential town or district. When new waterworks are being constructed for a district, it is usual to estimate for works calculated to supply thirty gallons per head per day ; but this is not because in well-regulated works the consumption reaches to that quantity, but to provide for a maximum supply being at hand during the driest season of the year, when the consumption is at its greatest. This quantity, however, is in many cases exceeded, notoriously so at Glasgow and New York, while in London it amounts to upwards of twenty-eight gallons per head per day. But as examples of what it should be where proper regulations to prevent waste are adopted, it has been incontestably proved (by Mr. Ayris M. Inst. C.E.) that in the case of Norwich and Sheffield, that a supply in the former case of fifteen gallons, and in the latter of eighteen gallons per head per day suffices for all wants, domestic and otherwise.

It is evident, therefore, that by a proper system of supervision, and the enforcement of the use of proper waste-preventing apparatus, the supply may be kept, under ordinary circumstances, within the above limits, without any way stinting the supply.

Another notable case is that of the city of Amsterdam, where the author's firm constructed the works. The supply is constant, and there are no less than 1137 tread consumers supplied by meter, but the total consumption per head per day, for all purposes, even in the hottest seasons, does not exceed fourteen gallons. This company, unlike the London Water Companies, had the great advantage of prescribing proper fittings from its commencement, in 1856; and this circumstance, combined with the fact that the W.C.'s are not connected with any system of main drainage, accounts for the small quantity of water supplied, which, however, is ample for the wants of the inhabitants, notwithstanding the notorious fact that the consumption of water for washing purposes, in Dutch households, is abnormally large.

The most fertile sources of waste of water, and yet the most easily preventible, are those from the W.C., and the overflow pipe from cisterns, which frequently leads direct to the drain; the former is remedied by the employment of a service box placed between the supply pipe and the W.C.; and the valves for the ingress and egress are so arranged, that before the latter is opened, the former must be closed, so that no direct communication can take place between the main and W.C. itself. The waste from the overflow pipe is avoided by breaking the connection between the pipe and the drain, by converting the overflow into a warning pipe, fixed in such a position that whenever an overflow or waste of water takes place, it can be seen by an inspector from the outside of the premises; or it is so arranged as to flow into some inconvenient place; in either case it insures the cause of waste being speedily discovered and the cause removed.

The "detection" of waste is more difficult than its prevention; for whereas the latter can, when once discovered, be checked or stopped by well known simple mechanical contrivance (*e.g.*, those above referred to and described in Clauses 11, 12, and 20 of the Portsmouth Water Company's regulations annexed hereto), it must be remembered that only a certain portion of the apparatus for conveying the water from the main to the house is exposed to the view of the inspector of fittings on behalf of the water authority; for instance, it frequently happens that, especially in certain soils, the service pipes are defective, and certain leaks may exist and remain undiscovered for years; the waste of water from this cause the author believes to be much greater than that usually attributed to it, and he believes much of it to be due to the employment of wrought-iron service pipes of inferior strength and quality. Many (hundreds of) instances could be quoted where such pipes have been found, after only a few years' use, to be decomposed from the outside, leaving the fibres of the iron stretched like violin strings, and barely holding together; imperfectly made joints or connections, or careless workmanship, or broken pipes from unequal subsidence, are also causes of underground leakages. To ascertain their extent and position forms an important feature in any thorough system of water inspection.

Until a few years since, the detection of underground or concealed waste of water by scientific or semi-self-acting means was comparatively unknown, but since the advantages of the constant service system have been more generally acknowledged, and the absolute necessity of preventing water waste admitted, much attention has been paid to the subject, and reliable mechanical means are now available for detecting, isolating, or concentrating at any particular point or district any waste that may be going on. The instrument known as "Deacon's Waste Water Meter," the invention of Mr. G. F. Deacon, M.Inst.C.E., is at once not only a waste detector and localiser, but also a self-acting silent registrar of the exact extent and amount of the waste at any particular spot. A detailed description of that instrument was given in a paper read by Mr. Deacon at the Society of Arts, on May 17th, 1882; it is therefore unnecessary to repeat it here, further than briefly to describe it as a self-acting registrar of the velocity at which the water is passing through it any moment, the result being registered by a diagram on a sheet of paper, placed on a drum worked by clockwork. This instrument is so sensitive that, in the words of the inventor, "in a main supplying 3000 or 4000 persons, the opening of a single tap is shown by a sudden fall in the line, and the quantity per hour by the difference in the flow before and after the opening; if the closing of the tap is shown, the duration of the flow is obvious also."

The extent to which waste has been reduced in Liverpool and other large cities by the employment of this meter, is matter of notoriety in the waterworks world; the author begs to add his personal testimony to the advantages gained by its use at Portsmouth, as shown in the following table:—

BOROUGH OF PORTSMOUTH WATERWORKS COMPANY.

TABLE SHOWING RESULTS OF USE OF DEACON'S WASTE WATER METERS.

District.	Number of services.	Estimated Population.	Date of fixing Deacon's Meter.	Reduction per head in Daily Supply.	Total Reduction per day.
				Gallons.	Gallons.
Queen-street	217	1,085	October, 1882	3	3,255
Daniel-street	626	3,130	September, 1882	13	40,690
North-street	550	2,750	June, 1882	3	8,250
Charlotte-street	1,100	5,550	November, 1882	12	66,600
King's-road	796	4,776	May, 1883.	12	57,312
Fratton-street	857	4,285	July, 1883.	9	38,565
Greetham-street	512	2,560	,,	9	23,040
St. James'-street	530	2,650	May, 1882	24	63,600
Hanover-street	360	1,800	April, 1882	18	32,400
Havant-street	227	1,135	June, 1882	14	15,890
Broad-street	252	1,260	January, 1882.	43	54,180
Barrack-street	125	625	February, 1882	25	15,625
Warblington	420	2,100	,,	28	58,800

Waterworks authorities have now, therefore, at their command both the means of detecting waste, and, having detected it, of requiring proper waste-preventing apparatus to be used, *i.e.*, assuming that they possess the necessary statutory powers; in cases where such powers do not exist, their necessity is so obvious that there is but little difficulty in obtaining them from Parliament, under proper restrictions. In the case of the metropolis, the necessary regulations were determined by a Committee appointed by the Board of Trade, in 1871, and the operation of the clauses in the Metropolis Water Act, 1852, requiring the London water companies to furnish constant supply, which had lain dormant since that time, at once commenced, and considering the Herculean proportions of the districts included within the radius which those companies supply, great progress has been made. From 52,265 houses receiving the constant supply in 1873, the number have increased as follows:—

1874	59,281
1875	70,160
1876	75,016
1877	97,343
1878	122,242
1879	138,624
1880	160,674
1881	185,076
1882	203,443
1883	226,376

Hitherto the author has only dealt with the supply as affecting private consumers, whose use of the water is presumably limited to domestic purposes. We have now to consider the question also of the supply to manufacturers and those cases where water is consumed for other than domestic purposes.

The introduction of water meters, for the purpose of measuring the quantity of water actually supplied to any consumer, has materially simplified the mode both of supplying and charging for water employed for manufacturing, or purposes other than domestic. Formerly, it was exceedingly difficult to form an accurate idea of the quantity used, especially at public institutions or large works, where frequent inspection was almost impracticable; re-surveying of premises, to ascertain whether additional supplies were being used, and the alteration of the annual charge for water, was a source of perpetual disagreement between the suppliers and the supplied. The water meter has, however, put an end to this, and proved equally advantageous to all parties interested. By its introduction an enormous amount of waste of water has also been detected, in many instances, to a large extent. One notorious case occurred in the metropolis. At a well-known popular restaurant, the water company having erected a meter, the quantity registered as passing it was so enormously in excess of the amount previously paid by the proprietor, that he naturally complained to the company. The meter was thereupon tested, but found to be accurate. Unconvinced, however, the proprietor threatened to have the supply cut off, and to resort to a very fine spring which he had in the basement of his premises. He commenced operations accordingly, only to find that the "very fine spring" consisted of a leakage from a broken pipe, which had been, doubtless, running for years, and which of course accounted at once for the abnormal consumption recorded by the meter.

As regards the most desirable water meter to be used, it is so large a question as to be worthy of a distinct paper. Speaking generally, however, those in practical use may be divided into three classes:

No. 1. The low-pressure meter.
No. 2. The inferential meter.
No. 3. The positive meter.

The disadvantage of the low-pressure meter, which is constructed much upon the same principle as the gas meter, the quantity being measured by the filling and emptying of compartments in a revolving drum, is that it must of necessity be fixed at (or rather above) the highest point where the supply of water is required, thus making it more expensive to fix, in consequence of the extra length of service pipe required, and more difficult of access for inspection; it also affords the opportunity to the consumer of fraud, by making connections to the pipe between the main and the meter; and although this latter may not be considered in the great majority of cases an objection, it is at any rate not desirable that the opportunity should be given. On the other hand, there are many instances in which—especially where large quantities of water are supplied in bulk into a large reservoir from one community to another—this meter may be applied with peculiar and especial advantage.

The second, or inferential meter (usually known as Siemen's meter), is based upon the principle of the reaction turbine, or Barker's mill, and is set in motion by the passage of water through it, the velocity of rotation being checked by veins, or plates, projecting from the revolving drum.

The author has some thousands of these meters now at work under his charge, and taken as a whole, their accuracy is surprising; it is quite true that, under very exceptional circumstances, *i.e.*, when the water is drawn off in minute quantities (or the capacity of the meter is much greater than its work), a certain quantity can be passed without registration; but in practice this does not take place to any appreciable extent, except in the case of large-sized meters, as, if the draw-off outlet is reduced to such an extent as to affect the working of the meter, the quantity passing is so small as not to reach the minimum annual water rent which the consumer is usually bound to pay, even if the consumption has been below a certain amount. These meters have the advantage of being moderate in price, compact, and liable to a comparatively small amount of wear and tear.

3. The positive meter, of which there are many varieties —*e.g.*, Kennedy's, the Manchester, and Tylor's,—measures, as its name implies, the actual quantity of water displaced by one or more pistons, which are themselves worked by the pressure of the water. These meters are, however (with the exception of Tylor's) more expensive and more

bulky than the inferential meters; they are, in fact, machines and require the attention of machines; at the same time, under proper management, they are not liable to get out of order, nor more costly for repair. At one waterworks which the author designed, every house is supplied by a Kennedy's water meter, at a price per 1000 gallons; a minimum rent being paid to the Water Company, proportionate to the size of the premises supplied.

In the foregoing remarks the author has endeavoured, he fears somewhat imperfectly, to compress within the limits assigned to this paper a synopsis of the various primary points in connection with the distribution of water. Were he to have attempted to go into detail, the paper could have been materially extended, but he trusts that he has said enough to draw the attention not only of those connected with water and water supply, who are already aware of the difficulties of the subject, but of those who are the recipients of the water supply provided for them at so much outlay, foresight, and trouble, to the very great importance of preventing the waste and misuse of so valuable an element. It is a notorious fact that all the available watersheds are being gradually occupied, and that year after year witnesses large communities being compelled to go to long distances for additional supplies of water. Glasgow to Loch Katrine, Manchester to Thirlmere, Liverpool to Vyrnwy, and the metropolis itself bound in the near future to resort to other sources as auxiliary to, or even possibly in substitution of, a portion of its present supply, all afford instances of this necessity; and hence the question of economy in the consumption of water is one the importance of which cannot be overrated. By all means let every individual, rich or poor, use abundantly all that is neccessary for every legitimate purpose, but beyond this let them be equally careful that no waste should be allowed. This is not only a duty of the consumers to the suppliers of water, but to their fellow-men, and while all who neglect it will deserve the reprobation, the gratitude of the community will be eminently due to those who will not allow one of the greatest blessings afforded to us to be diverted from its career of usefulness and benefit to humanity. To an audience like the present, largely composed of brother professionals, the author is aware that a great deal contained in this paper will not be new; but, on the other hand, there are, doubtless, those amongst the visitors to whom the subject is wholly or partially foreign, and he wishes this paper to be regarded not so much as a scientific as a practical paper, addressed to the community at large on an important domestic subject, in which every man has a direct interest.

DISCUSSION.

Mr. T. SUFFIELD wished to enforce the recommendation often made by Sir Francis Bolton, as to the arrangement of overflow pipes of cisterns. The ends of such pipes should discharge into the open air, or into a rain-water pipe unconnected with the drains. He thought it would be well for water companies to make an arrangement with plumbers, and offer small rewards to their workmen, for the discovery and prevention of waste of water. The fittings of cisterns were frequently defective, the ball-cocks being badly made and badly fitted. He objected to the removal of standing waste pipes; he thought that the upper ends of such pipes should be closed, and then, by lifting them out, the means was provided for cleaning out the cistern. The drains should be more frequently flushed, with a view to the removal of the causes of the stoppages. He laid great stress on the importance of a constant supply.

Mr. E. K. BURSTAL desired to say a few words with regard to the use of the waste-water meter. He would not cry down the use of that most useful apparatus which Mr. Deacon had invented, but he was quite certain that useful results could be obtained without that instrument. He had known himself, in two towns, that inspectors had to be sent round because that instrument merely showed that there was a waste, and they then had to send inspectors round to see where the waste was. He maintained that the use of that expensive contrivance might be dispensed with, and they might, by sending inspectors round with sounding rods and the necessary appliances, find out where the waste was, and check it, without using that apparatus. He might be thought old-fashioned in saying so, but he believed that to be the case. With regard to the cisterns which were generally in use for the supply of closets, he was much disappointed when he looked upon the exhibits of the London Water Companies in the Exhibition, and found the assortment of curiosities they had brought together. They had brought forward vacuum systems, and every sort of automatic system imaginable, but there was not one single instance of the double valve system, which had been introduced by Mr. Aris, some of which were now in use in Yarmouth, Lowestoft, Norwich, Derby, Leicester, and Oxford, and in all the towns noted for having a model consumption of water. In the towns of which he was managing engineer, they did not allow this automatic apparatus to be used, because they found they were waste-producers, not waste-preventers. In fact, to show how imperfect they were, one of the syphon systems could be set to run continuously, and that was a system which one of the London Water Companies was recommending for use. He really thought that, instead of introducing these patents to the public—and the public were consequently getting rather puzzled to know what to use—they should adopt such a plain double valve system as was placed before them, so that they could not both open at the same time. The advantage of a cistern upon that principle was that they would have for, say, a fourth or a fifth flushing, eight or ten gallons in reserve, and assuming a constant supply, if the water happened to be turned off for half an-hour during the day, they would still have a reserve in the cistern, and that would render the use of large 100 gallons or so cisterns unnecessary. They would then only have to put their taps on their rising service, and they would not want any cisterns at the tops of the houses at all. That could be done at very little cost in provincial towns, and it could be done in London. The remedy for the difficulty rested with the ratepayers, but the class of ratepayers who were the owners of small properties were the great obstructives. With regard to the water supply for fire extinction, the size of the service mains had not been taken into consideration for that purpose. It had been provided in all the local legislation that proper water mains should be laid down, and very few mains of less than 4 inches in diameter had been laid down since 1847; therefore, it was not right to say that provision had not been made for protection against fire; 1½ inch mains were sufficient for domestic purposes, but they wanted 4 or 6-inch mains for an efficient fire supply. Mains of that size had been laid in the town with which he had been connected from 1849 down to 1855. With regard to the dual system, they knew it was impossible to construct a service upon a principle of that kind. If one tap was placed beside the other, no one could ever tell which tap to go to, and the expense was a very strong reason against its adoption; and if what they had heard with regard to the quality of the water from the alarmists was true, which he, however, did not think was the case, it would not be a proper thing to put in the power of servants to give them contaminated water from the tap on the right hand sink when they were supposed to give them pure water from the tap on the left.

Mr. CHADWICK would say a few words with regard to the paper on fire prevention. In Liverpool, where a great deal of incendiarism prevailed, the chief magistrate came to ask his advice as to what they should do in the way of prevention, and he suggested that they ought to put the water on the constant system, hydrant the streets, and place the keys of the hydrants in the hands of the police, so that on the occurrence of a fire, there might be no loss of time, no running to distant stations, as the men would be able to apply it at once. That system had been adopted also in

Manchester, Glasgow, and in other places. A Committee of the House of Commons had also sat upon the subject, and it was shown that the effect of the adoption of that system was that they could bring the water to bear in about three minutes on the average; whereas, by sending for a distant fire brigade, however well organised, it was twenty or twenty-five minutes before they arrived at the fire. They afterwards improved their organization, and brought the time down to fifteen minutes, but Mr. Braithwaite, the late Chief of the Fire Brigade, stated, that for the efficient protection of life and property, you must have the assistance within five minutes, and this system brought it within three minutes. What had been the authenticated experience of its employment? Why, it had reduced the insurance risks in Manchester, Liverpool, and Glasgow, where this system was carried into effect, by fully two-thirds, or rather more, and the loss of life had been reduced in the same proportion. The Board of Works had raised objections to putting the keys of the hydrants in the hands of the police. There were 4,000 men always on duty, patrolling the streets at night, but they objected to their having them, and said they must keep the control to themselves. It appeared that in the mere greed of power, which had not hitherto been withstood, they would keep everything in a condition of insecurity to the public, by keeping the keys out of the hands of the police, who could act immediately upon receiving information of a fire, and that in the face of the experience as to the saving of two-thirds of the losses by fire! There were double as many police-stations as there could be fire brigade stations, and he could not imagine how anybody could insist upon their separation for this purpose, at the expense of an enormously great destruction of life and property by fire. That system should also be applied in the theatres; the police had to be there for ensuring order, and they ought to have charge of all waterworks and appliances for the immediate extinction of fire. The most scandalous thing he knew was the ignorance of members of Parliament, who could go on acquiescing with the maintenance of the present system in the face of such facts. As to the dual principle of water supply, if they had any *recherché* system as to quality and quantity of water that was applicable, they might have a separate dual system, but they had heard that the result of softening the water, and bringing in soft water for consumption by a separate system, was that water would be brought in for washing and ablutionary purposes and for baths—for everything in fact which would be benefited by the introduction of soft water—yet in fact, though the benefit would be great, it was obvious enough that the streets could be washed with common water; and, on the whole, he had expressed the opinion that the separation was not worth while, and to that opinion he still adhered. In one district, where an inspector was sent to examine the effects of drinking the Thames water from a place highly polluted with sewage, the people laughed at the idea that they drank water; in fact they drank beer, and beer generally was drunk by the whole of the wage-earning classes. Such was their dread of drinking the water in one case, that when he went to look at a place in London where the finest water was delivered, viz., the Kent water, he was warned against drinking the water on account of the gases from cesspools making it a source of great danger. The reasoning was that the death-rate there, where they had the purest water of all, viz., the Kent spring supply, was higher than it was in other places, and the deduction from that was that the water was positively unwholesome. But it proved to be nothing of the kind, for the people did not drink the water. It was the rarest thing for them to do so; even when a mother went out with her children, she was very careful to provide beer for them, for fear of the danger from drinking the water.

Mr. JABEZ HOGG said it was very evident children did drink the water, and no doubt to that fact was due the increase in the death-rate among the infant population. With regard to the arrangement of the filter-beds shown in the building, no two of them were alike—no two water companies adopted the same size and proportion of filtering materials; some gave six or eight inches of sand for a surface layer, and others gave four or five. There was no uniformity in the arrangements for filtering water, and that showed that filtration was of far less importance than it was generally supposed to be. The water companies evidently felt that it was a matter of very slight importance whether they gave a filter bed of six or eight inches of sand or four or five feet. One of the readers of a paper had remarked upon the companies compelling people to remove their waste pipes; he should like to ask practical engineers a question upon that point. Water companies were not agreed as to the use of the waste pipes. Some years ago, he removed his own waste pipe, which went into the sewer pipe, and converted it into a surface overflow pipe. Two years ago, the New River Company sent him a compulsory order to remove this pipe, and put in another overflow pipe at the top of the cistern. He had to alter all his fittings at considerable expense, and at the end of two or three weeks he found the effects of the overflow pipe was to inundate his house, for on a fire breaking out in the neighbourhood, during the night, the cistern overflowed, and the water came down the staircases and spoiled his carpets. He expected to get nothing from the water company in the shape of compensation for the damage done by the overflow; nor for the great damage done to the basement by the damp. But for the company insisting upon the removal of old pipes, which had been working efficiently in his house for some years, the damage referred to would not have happened, and the only excuse for removal was that the company was going to give him a constant supply of water; two years had elapsed and the constant supply was still promised. A fifteen minutes' supply at 11 o'clock, and no other supply for the day, unless a fire happened in the neighbourhood, when the water was turned on again, and he was liable to an overflow, unless great care was exercised in the examination of ball-cocks. Then there were, again, dead ends of streets, and dead ends of the companies' pipes, which greatly polluted our water cisterns, and as one gentleman had stated, when these got emptied, they occasioned a semi-putrescent rush of waters into the sewers, or into house cisterns.

Mr. CHADWICK said there was one point he would mention with regard to waste prevention. In Manchester they had got it down to 17 gallons a head, and in other cases the same thing had been done. But these were cases where the water belonged to the Corporation, and it was the officer of the Corporation who went in to examine, and not of any trading company. That difference was the great reason for the failure of any attempt towards the reduction of waste in London. If things were done there as in Manchester, Liverpool, and other towns, he had no doubt that waste in the metropolis might be reduced even more than was anticipated. They anticipated a reduction of one-third in the waste, and if the matter were under a public authority, who ought to have the control of the whole apparatus, not merely of the mains at the doors, but the capillaried works within the houses, that reduction could be effected, but until they were placed on a public footing there would be no economy secured.

Mr. WALKER had intended to confine his remarks to the subject of waste, but he wished to answer one or two remarks of the previous speakers. A remark had been made about the warning pipes. They were led to infer, because there was no flow from the warning pipe, it indicated a want of supply. As a waterworks manager, he would say it indicated that the fittings were in good order. At the same time it was not necessary for works to belong to a company to have efficient supervision; and to show how these matters were looked after by a corporation, he would read part of Rule 16 of the Reading Corporation Waterworks regulations. "Every cistern shall be provided with an efficient ball-valve and warning pipe, and shall be fixed in such a position as to be easy of access for inspection." If warning pipes were fixed in such a position that when there was an overflow, or when they indicated that some of the fittings were out of order, and caused damage to the property of the consumer, he would say that the company's officers were to blame for allowing the warning pipes to be fixed in such a position that they would, by overflowing, destroy any property of the consumer. Then, again, with regard to filtered water, the supply with which he had to deal came from a river. He had tried several experiments with reference to filtration, and he had found that filtration took place almost at the surface of the sand. If they had a bed of sand two feet in thickness, they would find, after a few weeks' use, if they let the filter dry, they could lift the film off as if they were drawing a piece of damp paper off a table. He would not say that the thickness of sand should be reduced to a few inches or under two feet, but through even two feet of sand sometimes they would find living things in the mains. Perhaps a consumer would come and make a complaint about finding a fish or an eel in his supply, but it did not follow from finding them in the mains that the water was impure. He thought, however, when they found leeches in the water, they were justified in preventing children drinking it. Much had been said in the course of the morning with reference to cisterns, but as the morning had been wholly devoted to reading papers, and the discussion had been left to gentlemen who were well acquainted with the subject of water supply, he had refrained from saying anything. The remedy he thought was to have a constant supply laid on. If they were to take a bottle of river water that had passed through a filter, to all appearance it would be clear and bright; but put a stopper in that bottle, and seal it down, and in a month or so afterwards they would find there was a considerable deposit at the bottom of the bottle, and to all appearance they would say it was very bad or very impure water. Impure water for public use, he would say, was water that fish would not live in; and water that fish would live in was not impure.

The conversation where he was sitting during the morning, turned on water supply to houses, and a lady said she had had the cistern in her house cleaned out, and the deposit found in it consisted principally of soot from the tiles, but that did not show that the water was impure. Then with regard to the remark as to water supply for fire extinguishing purposes, the diagram on the wall was an answer to that. A dual supply is not required. A town having a constant supply, and the fire brigade arrangements being under the control of the police, they could, in a few minutes after the alarm was given, fix a standpipe, and begin playing on the fire, and if the pressure was sufficient, they could do much in keeping down a fire before the engines arrived. With reference to waste prevention, he believed the best means of effecting that is to have a thorough code of regulations, and to have those regulations properly carried out. Much had been said with reference to Deacon's meters. There were no doubt a good many waterworks managers present, and other persons who must have received circulars, in which it was stated that managers were exceedingly pleased with the efficiency of Mr. Deacon's invention. One gentleman had stated that previously to the introduction of that apparatus there was a waste of 80,000 gallons a day going on in one district. He should think if there was a waste existing in any town of 18,000 gallons a day, it showed ignorance on the part of the engineer or the Board of Directors, and that there must have been great neglect. In reference to that subject, he would read a return with regard to the town he was connected with, viz., Reading, which stated that in 1874, the nett consumption was 47·71 per head per day; in 1876, with an increase of population and an increase of services, it was reduced to 30·24 gross, or a nett consumption of 16·99. But the circumstances which affected one town would not apply to another; some towns had a much larger trade supply than others, and they could not, therefore, draw a fair comparison on that account. In 1884, with a population supplied of 52,000, the gross consumption per head during the hot weather was 34·61, and the nett 18·26. This increase was due to the fact that a very great quantity of water was used in Reading for road-making and for new paving works which were now being carried on; and in addition they supplied 130,000 gallons per day to one railway company, also 23,000 gallons for sewer flushing, and in the town there were upwards of 8,430 water-closets. All this was done without waste-preventing meters, and if waste-preventing meters were used, they must increase the cost of management. With all those circulars which were sent, they had not stated anything as to any saving in working expenses, and he considered that to be a very important matter indeed.

Mr. E. K. BURSTAL said he had heard instances of six towns which, under companies' management—although two had recently been transferred to corporations—were the best managed towns in England—Nottingham, Derby, Norwich, Stourport, and Sheffield; and in fact he believed, in two cases, they had been transferred to the corporations because they were so well managed.

Mr. DICKSON said Mr. Burstal had made some observations with regard to the exhibit of the water companies, complimenting them on the admirable collection of curiosities they had shown, but complaining that they had not submitted to the public those apparatus which they considered best adapted to the purposes of the population. He would remind the Conference, however, that when the Commission sat in 1871, the whole weight of evidence tended to show that it was desirable that companies should have the power of inspecting, examining, and approving fittings to be erected in the houses; but, to the surprise of most people who followed the inquiry, the Commissioners, at the end of it, said they felt bound to recommend that no such power should be given, because they feared it would have a depressing effect on inventions and improvements of water apparatus. Consequently, while Manchester had the power of approving the apparatus to be used, the London companies had no such power, and any kind of water fittings which complied with the standard of ordinary intelligence was deemed to be an efficient apparatus. The magistrates of the metropolis were the authorities to whom this question was relegated, and they were very reluctant to fine persons for having a defective water apparatus, if it could be shown that it would do what would in their opinion be ordinarily expected of some such apparatus. The consequence was that companies, knowing this weakness, were obliged to pass fittings which, if they had proper authority, they would possibly be able to exclude. The companies, therefore, were not in a position to bring before the public any exhibit which they could recommend for adoption, for if they did, there would be an outcry on the part of this or the other inventor that his invention was superior, and the companies would incur a great deal of odium in addition to what they at present experienced. With reference to the question of warning pipes, he would remind Dr. Hogg that the regulation in this respect said that the overflow in connection with drains should be removed within a certain time, or at the option of the consumer should be converted into a warning pipe, and that every warning pipe so connected with the cistern should be placed in such a position as to be easy of access and inspection by the company's inspector; and he doubted not the reason of the remonstrance of the New River Company to Dr. Hogg on this point was that the pipe which he placed to his cistern, in substitution of the overflow pipe, was not so arranged that it could be seen by the inspector, otherwise he should not imagine any water company would require a consumer to provide an overflow pipe. In fact, every water company would be glad to see any overflow pipe in the sense of one which took an overflow from a defective valve-cock, done away with. A warning pipe was a very useful thing, if properly placed and connected, as a sanitary convenience, as it introduced fresh air to the surface of the water. With reference to the paper on fire extinction, he thought there was rather too sweeping a condemnation of the London supply, which the writer said was deficient in pressure. It was stated that in London the whole water supply was pumped (see *ante* p. 63), which would very likely be misunderstood ; the author was comparing the cities where the supply was by gravitation with other places where it was pumped. In London, as far as the fire supply was concerned, it might be stated to be by gravitation, because the water was pumped into reservoirs, which formed a head for the fire supply, just as much as in other towns where the supply was by gravitation without pumping. Then the writer stated that the average pressure was quite inadequate for fire extinction without the intervention of fire-engines, and again further on, he said the supply was undeniably deficient. He might appeal to the memory of Mr. Chadwick, who was present at the inquiry referred to, whether the general effect on the mind of the committee was not that the average pressure was quite sufficient for ordinary requirements of the fire brigade. The pressure in any town would scarcely be such as would enable the public authorities to do without engines ; in fact, it would be the most injudicious thing for any authority in London to have such a high pressure as to do without engines entirely. He would recommend the author of the paper to inquire of the fire brigade authorities for the results which accrued from the adoption of hydrants in the City of London. He could inform him that at the large fire opposite the General Post-office, there were a set of hydrants provided by firms on their own premises which were found to be of great use, and certain property would inevitably have been destroyed had it not been for those hydrants. Again, with regard to the Kent Company, it was shown before the committee that the pressure throughout the company's district was quite adequate for the purpose of the Fire Brigade if hydrants were provided, but the Metropolitan Board would not provide them until the company said that if they did not they would exercise the power of the Act enabling them to do it themselves, and thereupon they put up a few hydrants which were tried at large fires on the river side, where they were used without the intervention of steam engines, and the Metropolitan Board has since admitted that the pressure was adequate, and they had recently given an order for 200 hydrants to be erected in different parts of the whole district within the metropolitan area.

Mr. DEACON said he had only heard part of the discussion, and none of the papers, and would not have spoken had he not felt it desirable to throw in his experience against the objections which had been raised to cutting off sewer overflows from cisterns or replacing them by warning pipes. He had been instrumental in giving a constant service to a population of 700,000 or 800,000, in one place, and he believed at much less cost per head than had ever before been found sufficient. The quantity supplied was much less than under the previous intermittent service, and the methods he had adopted were now applied to many millions of persons, both here and in America. In Liverpool, the work had necessarily been done with comparatively little alteration of fittings. There were no such powers there as were possessed by some towns, notably Norwich and Manchester, where the corporations of companies had practically unlimited power to require the removal of fittings and to order any others to be put in. The secret of ultimate success in Liverpool, and in many other places, without oppressive regulations, was the multiplication, by a method often described but not always understood, of the means of detecting actual cases of waste by a given staff of inspectors, and the inclusion of hidden as well as visible waste. Of all methods, that must always be the best which can produce the required result at the least cost, and with the least annoyance to all concerned. Those who still believed in the antiquated method of house-to-house inspection had not tried the more modern method, and were not, therefore, qualified to speak concerning it. The many who had tried it on a large scale were, he believed, unanimous concerning its much higher economy and efficiency. With respect to the difficulty of not getting convictions from magistrates, there was comparatively little necessity for going before the magistrates, when the facility for detecting waste was so greatly increased. Persistent cases of waste were soon brought to bay, when the delinquents found that the trouble and expense to them of attempting to evade the doing of what was reasonably required by the officials was not worth their while incurring. The warning pipe was one of the instruments by which they succeeded, and he was exceedingly surprised to hear it suggested that some form of warning pipe should not be used. There was no doubt whatever that, unless you had some overflow apparatus which either made cistern waste a nuisance to the individual or visible outside to the public, that waste would go on to a very much larger extent than would otherwise be the case. It was not necessary to turn to Liverpool, as they were now discussing matters concerning London. The same thing had been done here. In the Lambeth district the waste had been so far reduced that, where the same methods were applied, the consumption and waste, instead of being between 30 and 40 gallons per head, as formerly, was now down to something between 15 and 16 gallons on constant service. If people had all the water they would take under high pressure and constant service, they had all that it was possible to give them. There should be no desire on the part of the authorities to prevent the use of water, but only to prevent deliberate harmful waste. If this were done, sanitary advantages, as he had elsewhere shown, must inevitably follow, as they had followed in Liverpool and elsewhere.*

Mr. MAXWELL said this question of waste was a very elastic one. They talked about getting the supply to under 20 gallons per head, but in some of the American towns it was up to 60, 80, 100, and 120 gallons. If you had a family of four or five, each of whom had a separate bath in the morning, using 40 to 50 gallons each, that would soon mount up. He was engineer to a town where the water-works belonged to the corporation, a dead level town. If he were the officer of a private company, it would be his duty, probably, to try and keep down all waste, to have no dribbling taps, and no water running otherwise than for some beneficial purpose; but the health of such a town as Hull depended on the water flowing into the drains, and as they could pay their way very well without being so sparing of water, and as they always had it to spare, he did not set himself so very dead against waste. They did set themselves against it in one way, which he would explain. Inspection was of two sorts; inspectors might go in and threaten and frighten people, but their inspectors did not; they kept all their consumers' valves, and washers, and ball-taps in order, and they found it paid them to do so.

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* See final remarks in discussion upon the paper by G. F. Deacon, read to the Society of Arts on the 17th May, 1882.

Mr. TARBOTTON, said he wished to say a few words on the general question, and principally with regard to dual supply. In all these public supplies, whether water, gas, or the disposal of sewage, a dual system, as a general principle, was to be condemned. They all knew the practical difficulties attached to these undertakings, and they also knew how very dangerous it was to allow a double system to be in operation. Of course there were exceptional conditions, and there were towns in Germany, and many other places, where it was perfectly easy to supply two classes of water; but in English towns he hardly knew an exception, except, perhaps, certain parts of the metropolis, where it would be possible and safe to carry out and introduce a double system. They knew what plumbers were in large mansions or institutions, and also what they were in small poor houses, and he was quite satisfied that two supplies ought never to be undertaken in London. The same thing applied to gas. You could supply gas at 12-candle power, or 18 and 20, but it meant duplication of services and mains throughout the whole system, and when you examined the amount of capital which had been expended on gas and water undertakings, it would be found, as a general rule, that the cost of the distributive service was 4-10ths of the whole, and that would have to be multiplied by two if a double system were carried out. With regard to the general question, he believed in the principle of constant high pressure service. They had had a high pressure service at Nottingham for nearly fifty years, without a single intermission, the pressure varying from 40 to 120 lbs. in all parts of the town, which system had been introduced by Mr. Hawksley. With regard to the prevention of waste, in a district which comprised a population of a quarter of a million, they had a very effective system of daily inspection carried out by specially trained men, and by that means they had reduced the domestic supply to a volume of something like 12 gallons per head; the total supply, including manufactories, being under 20. At one time it was something like 55. The same thing had prevailed in some other towns, where a similar reduction had been accomplished by the same means. The fire service was very effective, but they relied in a great measure on the pressure in the mains, which was sufficient to send the water over the highest warehouses and buildings; that, however, was supplemented by an efficient fire brigade.

Mr. SMARTT said he had a miniature farm or garden, by experiments with which he found that sewage water passed through boulder clay lost very little of its nutritious qualities.

The CHAIRMAN said he must now bring the discussion to a close, though several other gentlemen had sent up their names, for only a few minutes remained for him to offer some remarks on the chief points which had been discussed that day. It would be presumptuous in him to attempt to go over anything like the large range of subjects which had been dealt with; but he could not refrain from saying a word or two on the question of the quality of water, which had been one of the most prominent subjects under discussion. They must all regret that the very admirable paper of Dr. Odling had not been presented *in extenso* in print, and that they had not been enabled to examine the facts upon which he was quite certain the arguments had been based, which had led Dr. Odling to the conclusions he gave at the close of his paper. With regard to some of those conclusions, they would be all of one accord, viz., that the purity of water should, in the first instance, be considered by the chemist in its entirety; that what chemists called impurities did not necessarily relate to unwholesomeness: that, taking the actual proportion of organic matter existing in water, it was so small as to be of no importance in considering the quality of water for potable purposes, and also that organic matter which at one time might have resulted from decay, might possibly have no real importance with reference to the quality of water; that it might exist to a considerably greater extent in what was considered as the most wholesome spring water, than in the water of a stream. Again, with regard to his fourth conclusion, all who had studied the subject of so-called self-purification of water had come to the conclusion that this self-purifying power of a stream was very great indeed, and that the oxygen dissolved in the water, and continually re-absorbed by it—an action favoured by the agitation of the water in its flow—had the power of removing, to a considerable extent by oxidation, the organic impurities with which the stream might have become polluted. But when they came to the last two conclusions at which Dr. Odling had arrived, he must say that, in the absence of the facts upon which they had been founded, they still remained debatable; these conclusions being—that there was an absence of evidence as to the injurious nature of organic matter which might sometimes be found even in carefully filtered waters, and that there was no evidence that disease-producing organisms were developed or propagated in waters so filtered, so as to be prejudicial to life. All who had given any attention to the subject of the influence of water in promoting disease, would be inclined to hesitate before accepting the latter proposition; and they must, therefore, look forward with great interest to the publication of the complete paper, which would, no doubt, give the facts and reasoning upon which this statement was based. It had been within his experience that water which had been considered as of the very highest quality, and which the advocates of deep wells would unhesitatingly pronounce to be of a high quality, had, after its supply for house use, proved a source of disease. This led him to refer once more to the question of tanks. There had been a much greater unanimity of opinion than on any former occasion with regard to the mischievous results which might arise in consequence of the storage of water in houses. Mr. Hogg had explained that, in hesitating to adopt the statement that tanks or reservoirs were injurious, he did not refer to open tanks, butts, or reservoirs, but to closed tanks, which he looked upon as harmless. Even so far he must confess he did not feel inclined to agree with Mr. Hogg, from the very fact he had already alluded to, that a house supplied with one of the purest of London waters—a deep well water—was visited by disease such as Mr. Hogg pointed out as consequent on the pollution of water by matters connected with zymotic diseases, although the tank was apparently perfectly closed. There was not the least doubt that this was due to the causes insisted on by Mr. Chadwick, that wherever tanks existed there might, unless very great precautions were taken, be a possibility of pollution by gaseous emanations from sources of pollution. This being the case, there could not be a doubt that the constant supply, and the absence of cisterns, were fundamental points in the supply of wholesome water. How far measures could be taken to guard against waste, he must leave to those competent to deal with this part of the subject, by some of whom it had been shown, during the discussion, that, at any rate, considerable advances had been made in this direction. He should imagine that no householder would hesitate, if he desired to obtain a high-class water, to adopt such precautions as might be reasonably within his power to guard against waste, and that everyone would willingly bind himself to use the water carefully, provided he were perfectly sure of the quality. Even though certain arrangements which had been suggested might be inconvenient or unsightly, there was no doubt the advantage they would secure in promoting the supply of thoroughly pure water at a comparatively moderate cost, would counterbalance any of these disadvantages, in the opinion of all sensible people. They had discussed as far as possible the question of the advantages and disadvantages of a dual supply, partly in reference to the large consumption of water for ordinary purposes, and partly in reference to the application of water to fire extinction, but the question evidently still required much further consideration. There had been one or two advocates of a dual supply; but others had pointed out, and he thought correctly, that very great difficulties existed, which some were inclined to think insurmountable. The distinct supply, on a very large scale, of water of ordinary quality, such as they would not use for potable or other domestic purposes, would involve an enormous outlay of capital, and it would be very difficult to insure the use of such water in a manner which would be really safe to householders. It was gratifying to find that, since they last held a Conference, there had been a considerable assimilation of views amongst those who were formerly much opposed on the chemical aspects of the question. There was now a very considerable concordance of views amongst chemical authorities, and so he believed they would find that, amongst practical men, some of the difficulties which appeared insurmountable would gradually vanish, and that by comparing ideas and experience, they would speedily arrive at a very great advance in connection with the water supply of large towns. He regretted that the special attention which London had received in the discussion had led to very little being said about the water supply of villages or small towns. This was a subject which no doubt required so much earnest consideration that it would be desirable, before long, to have a Conference at which to discuss the subject on the still broader basis of a national water supply. In connection with this there were several important subjects which had not been exhaustively discussed, such as the question of the value of different systems of wells which were applicable on a small scale with comparative readiness, and the very important question of the extent to which purifying agents could be applied to water for small communities. They knew how valuable had been the results of Dr. Clark's process when applied so intelligently as it was, many years ago, by Mr. Homersham and since by various others, such as Mr. Porter and Mr. Atkins. In some instances, water which it was almost impossible to use for domestic purposes, on account of its exceeding hardness, had become an excellent water by application of this method of treatment. He had personal experience of this, inasmuch as he took part in experiments which Dr. Clark made when he softened water at the works at Plumstead, about thirty years ago, and had since had the supervision of softening works erected for the supply of water from deep wells to the Herbert Hospital at Shooter's Hill. What had been so successfully accomplished at this place, and elsewhere more recently by improved processes, had demonstrated how readily water might be treated when the supply required was comparatively moderate. The same system had even been applied to towns and districts of some considerable size; but the question still remained to be determined whether it would be possible to apply this excellent process upon so large a scale as would be necessary in order to supply London, or the more important districts of it, with softened water. That the Kent Company had hesitated to apply this system to the deep-well water supplied to Woolwich and elsewhere, which was most beautiful and wholesome to drink, but ill adapted to other domestic purposes, seemed to indicate that practical difficulties still existed which had to be encountered, not merely by the application of capital, but by science combined with practical knowledge. With regard to other methods of purifying water, considerable improvements had been effected in recent years in the application of filtering media, such, for instance, as charcoal preparations, and iron in a more or less finely divided condition. If water were affected chemically by treatment with either precipitating or oxydising, or otherwise purifying agents, such treatment must be efficient in proportion to the amount of surface of water brought into contact with the agent applied. If iron exerted a purifying influence on water, it would obviously exert that to the greatest extent within a given time, if the surfaces of the iron and the water coming in contact were constantly renewed. That this was done to a considerable extent in a filter there could be no doubt, but when a column of water was passed through a column of filtering material, the latter must present channels in parts, admitting of the free passage of the water. By passing through these the water must to some extent escape being purified; but if you took the same purifying agent, and agitated it for a short time with water, you renewed the surface of contact between the water and it continually and rapidly, and so, as a matter of course, effected in a short time what you had to apply a considerable amount of time, and a comparatively very large amount of purifying material, to effect to anything like the same extent by the ordinary methods of purification by filtration. There could be no doubt that the action of charcoal as a purifying agent, quite apart from its action as a simple filtering agent, was much promoted, like that of iron, by constantly renewing the surface of contact between the charcoal and the water, and so he should imagine that filtering on the principle devised by Mr. Maignen, or other filters based on similar principles, would act more efficiently and rapidly than the mere passage of water through charcoal *en masse*. No doubt much had to be learnt with regard to the treatment of water by means of domestic filters, which would always be important in connection with the supply of small communities, and that of groups of people like soldiers on active service. A filter was popularly expected to accomplish two things: in the first place, it simply strained or clarified water, by separating suspended matter, and a properly-built filter might be relied upon to carry out this operation for a considerable period, until, in fact, the passage of the water was too much impeded by the clogging effect of the impurities deposited in the filter. Secondly, some filters would to a small extent purify water of dissolved matters, but it was important to bear in mind that that power could only be retained by a filter for a comparatively brief period. Many people bought a filter, and having set it up, they did not care much what the source of water was which they used, being satisfied that, by having bought one of the best forms of filter, and drinking nothing but the water filtered through it, they were secure against all evils ascribable to water. But that filter might, and was generally, filled month after month, and even year after year, and was supposed to continue perfect as long as the water ran through it, and was not even suspected of being inefficient until it became actually choked up. This was one of the most dangerous points connected with the application of filters to domestic purposes, and too much stress could not be laid upon it. He begged, in conclusion, to congratulate the Society upon the useful nature of the discussion, elicited by the valuable papers which had been brought before the Conference.

Mr. EDWIN CHADWICK then proposed a vote of thanks to the Chairman, which was carried unanimously, and the proceedings terminated.

The following letter from Mr. W. Whitaker refers to his paper read on the first day (see *ante* p. 4) :—

There having been no time for the authors to reply to the points raised in discussion, I send the following note on what fell from Mr. Baldwin Latham, and from Mr. Kinsey, in regard to the chalk marl on the south of London and near Petersfield, allowing of the passage of water between the chalk above it and the upper green sand below. In my paper the suggestion that another colour might have to be added to those already used on my maps to separate the chalk marl from the rest of the chalk, is not of universal application ; but refers only to those parts where the chalk marl is so clayey as to be practically water-tight and not water-bearing. The district in my mind was not that on the southern side of the London basin, but that on the northern side, where, for very many miles in Hertfordshire, Bedfordshire, Cambridgeshire, and part of Norfolk, this basal part of the chalk is so impermeable as to throw out water from the permeable bed of hard and somewhat sandy chalk that overlies it. The outcrop of that permeable bed, known as the Totternhoe stone, and which has been largely used in building, is marked by a line of springs the occurrence of which has determined the site of the many villages to be found along the base of the chalk hills from Hertfordshire to Cambridgeshire. The conditions here are clearly different from those that hold on the southern side of the London basin ; but I doubt if in the latter district the chalk marl everywhere allows the passage of water through it, and evidence in this direction is given by the experimental drift-way of the Submarine Continental Railway, near Dover, which, driven through chalk marl, was practically dry. To show, however, the varying nature of this bed, as regards water, we need only cross the Channel, to the corresponding experimental works of the French Company, where many springs were met with in the chalk marl. At Dover the only fluid found was champagne, and it is said that this was dry !

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LONDON, 1884.

CLEANSING STREETS AND WAYS

IN THE

METROPOLIS AND LARGE CITIES.

BY

WILLIAM BOOTH SCOTT,

MEMBER INSTITUTION OF CIVIL ENGINEERS;—CHIEF SURVEYOR TO
THE VESTRY OF ST. PANCRAS, ETC.

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MEMORANDUM.

I AM indebted to the courtesy of SIR JOSEPH WILLIAM BAZALGETTE, C.B., for the comprehensive Table between pages 16 and 17, and to MR. D. KINNEAR CLARK for valuable assistance ably rendered in collecting and marshalling some of the general statistics—those especially relating to foreign cities.

WILLIAM BOOTH SCOTT,
M.Inst.C.E.

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CLEANSING THE STREETS AND WAYS
OF
THE METROPOLIS
AND OTHER LARGE CITIES.

THE health of the inhabitants of a great city must be materially affected by, and to great extent depend upon, the efficiency of means adopted for the removal of refuse;—for the timely and periodical cleansing of the streets and carriage-ways within its precincts, and for the preservation of those thoroughfares free from offence or obstruction.

The work to be done is of itself very simple in its nature, and becomes difficult only by reason of the enormous aggregate quantities to be removed, and dealt with, from overgrown communities; by the want of consideration evinced by the individual members thereof, and in many cases—the Metropolis for example—by the existence of concurrent jurisdiction set up by different Acts of Parliament, the result of slovenly indefinite legislation—legislation that would seem almost to justify the opinions openly expressed by cynical, atrabilarious critics, that the lawyers in Parliament take care that the measures passed shall be so framed and worded as to provide plenty of work for their brethren of the long robe.

DEFECTIVE LEGISLATION.

Concurrent jurisdiction is not the only result of modern insincere and indefinite legislation. Existing Acts are incorporated wholly or partly in Bills under consideration or altered or repealed by means of "schedules" or otherwise, sometimes in such terms as these :—

> "*All the duties, powers and authorities for or in relation to the paving, lighting, watering, cleansing, or improving of any parish mentioned in Schedule* (—) *to this Act, or any part of such parish, now vested in any commissioners, or in any body other than the vestry of such parish, or in any officer of any commissioners or other body, and all other duties, powers, and authorities in anywise relating to the regulation, government, or concerns of any such parish or part, or of the inhabitants thereof* (*except such duties, powers, and authorities as relate to the affairs of the church, or the management or relief of the poor, or the administration of any money or other property applicable to the relief of the poor, so far as such duties, powers, and authorities relate thereto,*) *now vested under any local Act of Parliament in any commissioners, or in any body other than the vestry of such parish, or in any such officer, shall cease to be so vested, and shall save as herein otherwise provided become vested in and be performed and exercised by the vestry of such parish under this Act;*" *&c. &c.*

or by such as this :—

> *All Acts of Parliament in force in any parish or place to which this act extends, or in any part of such parish or place, shall, so far as the same are inconsistent with the provisions of this Act, be repealed as regards such parish or place, or such part thereof, notwithstanding any provisions of this Act continuing and transferring respectively to vestries of parishes and transferring to district boards any duties, powers, or authorities now vested in vestries, commissioners, or other bodies.*"

or by such as this :—

> "*The powers of improving and regulating streets and for the suppression of nuisances contained in the Act of the*

fifty-seventh year of the reign of His Majesty King George the Third, chapter twenty-nine, local and personal, intituled "An Act for better paving, improving, and regulating the streets of the metropolis, and removing and preventing nuisances and obstructions therein," shall, so far as the same is in force, and is not inconsistent with the provisions of the recited Acts and this Act, extend and apply to the metropolis as defined in the firstly-recited Act and in this Act, including any unpaved streets, and notwithstanding any exceptions therein contained."

CLEANSING IN THE METROPOLIS.

In the Metropolis the duty of cleansing the streets and ways and of employing or contracting with any company or persons for that purpose is imposed upon Vestries and District Boards of Works, more especially by the 125th section of the Metropolis Local Management Act, and special power is taken to refer to such company or persons as scavengers.

A scavenger, according to the great lexicographer, is "a petty magistrate whose province it is to keep streets clean." By the provisions of the statutes conferring powers on Local Authorities (see Appendix A), it will, however, be seen that the functions of the scavenger are more comprehensive. He not only cleanses streets—but is expected to suppress dust, and remove mud, ice, snow, and much else from streets and from houses. These are among his functions by statute, and he is at least supposed to discharge them.

The refuse of streets and houses is heterogeneous in character. Besides the dust, mud, and occasionally ice and snow, there are found paper, rags, old mattresses, jewels, rings (sometimes wedding-rings), meat-tins, straw, cabbage-leaves, onions, bank-notes, apples, turnips, fish-bones, money (gold, silver and copper), dead cats, dogs, rabbits, guinea-pigs, fowls, horse-dung, refuse from slaughter-houses and fish shops, brush-heads, old boots, old books (some rare and valuable), knives, forks, silver spoons, children's toys, old hats, old bonnets, crinoline wires, umbrella frames, broken pots, broken bottles, preserve jars, and other crockery, medicine-bottles, old tin and iron wares, ashes, cinders, much coal of all sizes, firewood, broken bricks, door-mats, table-covers, floor-cloth, *et cetera.*

OBSTRUCTIONS.

The dirty and incommodious condition of some streets is the result of open violation of the provisions of the statutes. Obstructions are placed on the footways and the carriage-ways ; thousands of strolling cab-men are allowed to ply for hire (a contingency which is the unavoidable result of over-licensing, in London there being not standing room for more than half the licensed cabs), adding the cattle-droppings to straw refuse and litter swept out of shops ; carpets and mats are shaken in the streets ; snow lies on the footways ; garbage and refuse cast into the roadways ; offensive matters are spilt from carts, and even pigs in some localities are allowed to run about the streets ; just as if no prohibiting sections, relative to such nuisances, existed in the Police and other Acts.

It would appear that this irregularity in some respects is, more or less necessarily, connived at by the Police. The placing of costermongers' stalls outside the footpaths of and on the carriage-ways of streets (of great traffic, although not of absolutely first importance), is a practice which results in the rejection of much refuse into the carriage-ways. The toleration with which the stalls are regarded by the Police is an anomaly only to be explained by their undeniable convenience to large sections of the respectable poor, who are thus enabled to invest their limited means to the best advantage. Many shopkeepers entertain the idea that the out-of-door stalls are a hindrance to their trade and interfere with their profits ; and any shopkeeper can require the Police to remove stalls from his own frontage. But he cannot cause the removal of the stalls from his neighbour's frontage; and as no authority has power to cause the removal of the stall, unless at the request of the shopkeepers or frontagers immediately affected, the result is, practically, that the carriage-way, for a width of from seven to ten feet from the kerb, is occupied in permanence by the stallkeepers.

There are many streets of less traffic where costermongers could ply their out-door trades without such serious interference with public locomotion; but, upon the whole, it seems to be regarded as more convenient for the purchasers that the out-door stalls should be planted in the main thoroughfares, and it is questionable, after all, whether they materially damage the business of the shops, for the stall customers belong to a class who could not afford to purchase at all, or so largely, but for the very low prices charged at the stalls.

The positive advantages of the costermongers' stalls must, on reflection, be apparent to every one. They are the means by which the poorer classes obtain large supplies of food at the minimum of cost—sometimes wonderfully cheap. It is astonishing how quickly the news of a "glut in the market" circulates; how speedily the costermongers rush to the market, whichever it happens to be, and how rapidly they disperse throughout the Metropolis, necessarily disposing of their perishable stocks on the same day.

A superabundant supply enables them to purchase cheaply and advantageously; that they can sell cheaply enables them to clear out their stock quickly, and—to the poor—advantageously.

CONCURRENT JURISDICTION.

In this matter of the costermongers' stalls, as in many others, there is concurrence of jurisdiction with the Police and with the Local Authorities, each often leaving to the other the opprobrium of setting the law in motion. Moreover, it is found by experience to be impracticable to obtain convictions, such as would justify the Local Authorities or the

Police continuing endeavours to enforce the provisions of the various enactments for preventing the obstructions. In this matter of costermongers, as in the case of removal of snow, the residents or shopkeepers persist in defying the law ; numerous summonses excite the anger of a magistrate ; whereas, on the contrary, a few summonses, taken out against typical offenders, are likely to be held up as evidence of persecution direct against particular individuals.

Concurrent jurisdiction is the fruitful cause of much inconvenience, and indeed neglect, especially where the enforcement of penal clauses is involved, as the executive officials of the respective authorities are naturally anxious to leave to others the invidious duty of applying stringently the punitory enactments of the statutes.

EXAMPLES.

CLEANSING FOOTWAYS.

The duty of enforcing the *Cleansing of Footways* from mud and snow by occupiers, is placed upon the Police by the Police Act, 1836. The same duty is imposed upon the Vestries and District Boards by the General Paving (Metropolis) Act, 1817, by incorporation with the Metropolis Management Act, 1855, " as far as may not be inconsistent ; " by which latter Act also the Vestries and District Boards *may* do the work themselves. The execution of the work by the Local Authorities is not compulsory, but only permissive. Authorities that frequently omit to do work that the statutes declare they *shall* do are not likely to do that which it is enacted only that they *may* do ; and so it remains undone, and not one occupier in a thousand ever causes the footway in front of his premises to be cleared of mud.

COSTERMONGERS.

The *Regulations of Costermongers* is generally understood to be the duty of the Police, as the Traffic Regulation Act of 1867 gives the Chief Commissioner of Police power to make regulations for control wherever stalls are allowed to be pitched in what are called market streets ; but the concurrent powers of the Vestries under the Metropolis Paving Acts, by incorporation, are not impaired, and they hold the right equally with the Police to prohibit the placing of goods for sale on the public way, whenever it is deemed expedient.

OBSTRUCTIONS.

Obstructions caused by shopkeepers exposing goods for sale on the public way are controlled by the Police, under their Act of 1839, and by Vestries, under powers by succession under the Metropolis Paving Act, 1817 ; but each use discretion in selecting cases for proceeding. Increasing apathy is evident on the part of the Police, by a tendency to shift responsibility on to the Vestries, whose proceeding under the statute is discretionary, while the Police are absolutely enjoined to take action against offenders, but in general abstain from action.

PROJECTIONS.

Projections into Streets, which may constitute annoyances or obstructions, are touched by the Metropolis Local Management Act of 1855, as well as by the Metropolis Paving Act of 1817 ; while those which constitute distinct obstruction are also under the control of the Police under the Act of 1839, and the District Surveyor's powers, under the Building Act of 1855, applies also to the same projections.

PIGS.

The *Keeping of Pigs* in the Metropolis is controlled by Vestries and District Boards of Works, specifically under the Metropolis Paving Act, 1817, and generally by the various Nuisance Removal Acts passed since 1855 ; and the Police have power in certain cases under the Police Act of 1839.

SWEEPING SLOP INTO GULLIES.

The offence of *putting slop or mud down gullies* and sewers is punishable by action on the part of Vestries, under the Metropolis Local Management Act, 1855, and by the Metropolis Paving Act, 1817 ; concurrently by the Police, under the Act, 1839, it being an offence that calls for much vigilance ; and the Metropolitan Board of Works have also like power, so far as the offence may affect the sewers under the jurisdiction of that Board.

CONSTRUCTION AND MAINTENANCE OF ROADS.

It has frequently been remarked, that well-made and well-kept roads are at the root of civilization. No nation ever made much progress in civilization that neglected its roads. The Turk, certainly, was never a road-maker.

Round boulder pebbles, such as may still be found in neglected ways in the poorest districts of large towns in England, paved probably two hundred or three hundred years ago, would constitute a first class Turkish road. So in Egypt, where dust lies on the roads a foot thick, and when visited—on rare occasions, it is true—by heavy showers of rain, the mud so formed constitutes a formidable impediment to locomotion.

The desire for progress, indicative of the advance of civilization, will beget attention to the construction and maintenance of good roads—the existence of good roads will facilitate the advance of civilization.

Macadam introduced the system of forming roads of broken stones of uniform size ; and roads on this principle serve admirably for highways in country districts.

Roads on this principle have also been laid in the streets of the Metropolis, and of nearly every town in the kingdom. For thoroughfares of small traffic in cities they answer comparatively well ; but under heavy traffic a macadamized road becomes but a mill, the stone being ground up in wet weather into mud, and in dry weather into dust.

London street mud is a noxious and destructive compound, injurious to clothing, to carriages, and to harness. It has been stated by Mr. H. Graves, the eminent print publisher, that he can clean an engraving from oil, or from ink, or from ordinary dirt, but not from London street mud. To casual observers it is a matter of surprise where all the mud comes from.

The test of comparative excellence in paving is the quantity—more or less—of mud seen upon the surface. The mud found upon a paved street is not so much the result of the wear of the pavement, as of the working upwards of the sub-stratum through defective foundation upon which the pavement has been laid. This applies to wood as to stone pavements. The imperfect foundations supply, however, only a part of the refuse that accumulates in the streets. The dust and mud of the streets of great towns consist, in addition, generally of four ingredients: stone, horse-droppings, shoe-iron, and shoe-leather. House-refuse is not an unknown element; it counts for something in the mass of stuff that is collected in and removed from the streets and roads. Dr. Letheby, in 1867, analysed dry mud from the streets of the City of London, dried by exposure for many hours to a temperature of from 266° to 300° F. At the same time he analysed for comparison samples of well-dried fresh horse-dung and common farm-yard-dung. The results of the analyses are given in the following table.

Composition of Mud from Stone-paved Streets, Horse-dung and Farmyard-manure, Dried at 300° Fahr.

Constituents.	Fresh Horse-dung.	Farm-yard Dung.	Mud from Stone-Paved Streets.		
			Maximum Organic. (Dry weather.)	Minimum Organic. (Wet weather.)	Average.
	per cent.	per cent.	per cent.	per cent.	per cent.
Organic . .	82·7	69·9	58·2	20·5	47·2
Mineral . .	17·3	30·1	41·8	79·5	52·8
	100·0	100·0	100·0	100·0	100·0

The higher proportion of mineral matter in wet weather, shown in this table, proves that in such weather the abrasion of stone and iron is greatest. Dr. Letheby estimated that the average proportions of stone, iron, and dung in the dried muds were—

	Per cent.
Horse-dung	57
Abraded stone	30
Abraded iron	13
Total	100

The mud was so finely comminuted that it floated freely away in a stream of water.

In mud produced on wood pavements in the City of London, the proportion of organic matter naturally was larger than in that produced on stone pavements, the proportion amounting to about 60 per cent.

The variation in the amount of moisture in the mud of stone pavements was found to be (according to the state of the weather) thus :

MOISTURE IN MUD OF STONE PAVEMENTS.

In the driest weather	rarely less than	35	per cent.
In ordinary weather	„	48½	„
In wet weather	„	70 to 90	„

A far greater proportion of the detritus of macadamized roads is, however, composed, as may reasonably be expected, of the abraded material of the roadway itself. A cubic yard of broken stone metalling of the ordinary size—2 inches or 2¼ inches cube—when screened and beaten down in regular layers 6 inches thick, contains, according to the late Mr. Joseph Mitchell, of Inverness, 11 cubic feet of interspaces, as tested by filling in with liquid. Herr E. Bokeberg, of Hanover, made many careful experiments to ascertain the proportion of vacuity to solid material, and found that in a loosely-heaped cubic yard of broken stones, void space amounted to one-half of the total volume. With stones that had become rounded at the edges and corners by wear, the vacuities were reduced to 37 per cent.

of the gross bulk, or to 10 cubic feet. These results would seem to indicate that the interspaces in the case of new stones were reduced by compression to nearly the same volume as was attained after the edges and corners had been rounded by exposure to wear. The original mass of 16 solid cubic feet of broken stone is, in fact, crushed into fragments of every variety of form, eventually down to the finest particles, producing mud, a small proportion only of the stones remaining of their original dimensions.

Mr. Mitchell gives the result of an analysis of 2¼ cubic feet of the macadamized road in the Mall in St. James's Park, which was taken up for examination. The component parts of the sample were carefully separated and classed, when it was found that one cubic yard contained:

	Cubic feet.	Per cent.
Mud	11·00	41
Sand, with pebbles not exceeding 3/16 inch thick	2·40	9
Stones from 3/16 to ½ inch	6·56	24
Stones from ½ to 1 inch	4·48	16½
Stones from 1 inch to 2¼ inch	2·56	9½
Total volume 1 cubic yard, or	27·00	100

From the analysis it appeared that less than 9½ per cent.—say one-tenth—of the original stone escaped unground; whilst 40 per cent. of it was reduced to a state of mud. Even these proportions, taken as they stand, are too favourable for the duration of the stone in that instance, for no doubt the sample was a specimen of what remained of the stone, after much of it had been swept or washed out of sight. Mr. Ex-Sheriff Burt, who, commencing his career with the great road-maker McAdam, has the experience of a long lifetime in road work of every description, cannot be much amiss in his estimate that one third of the loose road material used in London is literally wasted by being ground up under the traffic before the consolidation of the surface is effected.

By far the greatest proportion of the detritus of macadamized roads consisting of the worn material of the road, the important principle was early revealed by experience, "that the oftener the streets are cleaned the less is the mud which is created and removed, whilst the attendant expenses are by no means increased, and the roads are kept in a better state of preservation." The principle is, besides, deducible from the fact that the loose particles, if left on the surface, act as a grinding powder under the wheels and the horses' feet, to reduce to similar powder the surface of the road, and that the mud which is formed with the detritus when rain falls upon and is mixed with it, operates as a sponge in retaining the moisture on the surface. The crust as well as the sub-stratum, under the circumstances, becomes saturated with moisture, softened, and "rotten," just as a gravel foot-path, hard and solid in ordinary weather, becomes sodden and pulpy when it is lapped for a time by a covering of half-melted snow. The macadamized carriage-way thus reduced, is by the traffic exposed to rapid deterioration, which increases with an accelerated ratio, producing an increased quantity of mud. These conclusions are strengthened and supported by statistics. Shortly after Sir Joseph Whitworth introduced his street-scraping machine in Manchester, it was ascertained by calculations made by the Municipal Authorities on the relative advantages of machinery and manual labour, that by cleansing the macadamized streets with the Whitworth machine three times a week, the quantity of mud produced on the surface was only one-fifth of what was produced when they were swept by hand twice in three weeks. The following are the comparative results.

MACADAMIZED STREETS.

MANCHESTER. Area of district, 5,500,000 square yards.

	Loads removed.	Average area swept to produce a load.
Swept by machine three times a week	1285	4388 square yards.
Swept by manual labour twice in three weeks, Township 1841–1842	6400	859

It was demonstrated by experience that, by the use of sweeping machines, with the proper use of water, a saving of fully one-third of the material required for the repair of the roads was effected in one particular district in the Borough of Birmingham.

Careful comparative tests of Smith's horse-sweeping machines versus land labour were made in the parish of St. Pancras in 1862, the leading results of which showed that a horse-machine, tended by four sweepers, sweeps an area equal to that swept by twenty-four men in the same time; and that the machine sweeps the surface so much more effectively, that it gathers up sixty loads as against forty-one loads swept up by manual labour. Each machine costs £30, and a horse and a man to drive cost 10*s.* per day. Eight machines would cost £240, and supposing that the machines were used on twenty days in the year, for dealing with exceptionally heavy slop, the annual cost was estimated as follows:—

8 machines, £240; 10 per cent. wear and tear.	£24	0	0
20 × 8 horses = 160, at 10*s.* per day . .	£80	0	0
Per year	£104	0	0

The evidence of the exceedingly greater wear of a macadamized surface than of a stone-paved surface is strikingly exhibited in the contrast of the comparative costs for cleaning the two kinds of surface. Mr. Royle states that in the spring of 1870 there were laid in Chester Street, Manchester, 10,000 square yards of granite pavement, and an area of equal extent of macadam. The condition of cleanliness of each was maintained uniform throughout the period of trial by sweeping, for which the respective costs were 9¼*d.* per 1000 square yards and 5*s.* 2½*d.* per 1000 square yards, being in the ratio of one to seven. The average cost for the whole year averaged in the ratio one to five. The great bulk of the excess for macadam, compared with pavement, must have been due to the vastly augmented wear of macadam granite.

Whilst the greater proportion of the mud of macadam consists of mineral refuse, the detritus of the material of a granite pavement constitutes but a small proportion of the total quantity of the mud-forming dust. Colonel Haywood strikingly exemplified this proportion on the granite pavement of London bridge, three-inch Aberdeen granite sets, which was removed in 1851, after nine years' wear. The average loss of granite, on an area of 3950 square yards, he estimated was equal to two inches of vertical wear. The total volume of granite worn away was therefore about 219½ cubic yards, assuming that the surface was a continuous mass of granite, though there was of course a considerable superficial area of joints. Assuming that the granite worn off was reduced to a state of fine powder, it was increased in bulk probably one-half, and its volume had been (219½ × 1½ =) 329¼ cubic yards. Adding 5 per cent. for the loss upon stones removed and replaced from time to time, the total quantity worn off and reduced to powder, and carried away, mixed with the dust of the street and mud, would only have amounted to 345·7 cubic yards for nine years, equivalent to an average of ·105 cubic yard, about one-tenth of a cubic yard per day. Whereas the quantity of dust removed daily, in dry calm weather, was from three to three-and-a-half cubic yards—above thirty times as much as the granite detritus. So much for horse-droppings, shoe-leather and iron, which must have contributed 29–30ths of the total accumulation. Of course in inhabited streets the house-refuse supplies considerable addition.

An approximate estimate of the comparative manurial value of the refuse from streets of stone pavement, wood pavement and macadam, may be based upon the preceding conclusions on the relative wear and tear, and the mud constituents. And first of stone pavements. The mud of paved streets contains from 35 per cent. to 90 per cent. of moisture, varying according to the state of the weather and the condition of the streets. The mean between these extremes, say 60 per cent. of moisture, may be taken at the average for calculation, leaving the balance 40 per cent. of solid matter. Fifty-seven per cent. of this proportion, according to Dr. Letheby, consists of horse-droppings, and therefore 57 per cent. of 40 per cent., or 22·8 per cent. of the mud collected, is the proportion of the manurial elements. The dried mud of wood pavements contained 60 per cent. of organic matter ; a little more than was found in the mud of stone pavements, equivalent to 24 per cent. of mud in average condition.

As it appeared from the results of Mr. Royle's observations that the quantity of mud collected from macadam was from five to seven times that collected from stone pavement, the proportion of organic matter on the basis of the observed proportion for stone pavements would not exceed an average of 4 per cent. of the whole quantity of mud collected from macadamized roads.

In support of the seemingly large average percentage of horse-droppings in the mud of the City streets, it may be added that in the parish of St. Pancras the " dry sweepings " from paved roads, whether of granite or of wood, have been estimated to contain 75 per cent. of horse-droppings.

MAGNITUDE OF QUANTITIES TO BE DEALT WITH.

An idea of the magnitude of the question of street-refuse in the Metropolis may be gathered from the comprehensive, but not exhaustively complete, table annexed, showing for each parish or district in the year 1878 the nature of the roadway formation, and the lengths of streets and roads constructed with granite paving, macadam and gravel, asphalte, wood and flagging ; the number of catchpits, and the quantity of solid deposits in catchpits and sewers ; the number of cart-loads of mud and dirt removed from the roads, streets, and alleys ; also the

1878.

Name of Parish or District.	Nature of Roadway Formation.															Total length of Roads, Streets, &c.			Catchpits under Gullies.				Quantity of deposits removed from sewers annually.	Cartloads of mud and dirt removed off roads, streets, &c., annually.	Total quantity removed in cubic yards.	Number of Flushers.	Quantity of Materials used.					
	Granite Cubes.			Macadam and Gravel.			Asphalte.			Wood.			Flagging.						How often emptied annually.	Capacity in cubic yards.	Number.	Cub. yards intercepted and removed annually.					Broken Granite.		Broken Flint.		Hoggin.	
	M.	F.	Y.	M.	F.	Y.	M.	F.	Y.	M.	F.	Y.	M.	F.	Y.	M.	F.	Y.									Yards.	Tons.	Yards.	Tons.	Yards.	Tons.
Bermondsey, S.	9	6	1	18	7	102	..	..	..	..	..	61	..	..	..	28	5	164	Frequently	No information	No information	540	443	12,379	13,362	7	2,489	..	..	..	..	..
Bethnal Green, N.	9	3	43	29	1	50	..	1	115	..	..	..	1	0	138	39	6	126	12	½	1,961	11,760	494	11,268	23,522	3	1,103	..	..	..	..	..
Camberwell, S.	1	0	0	101	4	0	..	..	..	..	4	0	..	..	..	103	0	0	1	¾	5,500	4,125	70	15,000	19,195	6	6,500	..	13,500	..	..	..
Chelsea, N.	1	4	17	27	6	180	..	..	..	..	..	179	..	..	..	29	3	156	8	1	2,000	8,000	40	10,800	18,840	5	..	9,500	2,000	..	..	..
City of London, N.	25	0	0	..	2	0	6	0	0	6	0	0	11	1	0	48	3	0	Frequently, say 4 times	½	1,486	2,972	300	30,000	33,272	20	..	..	..	..	..	..
Greenwich, S.	..	4	93	56	6	43	..	1	43	..	..	100	4	7	94	62	3	153	4	¾	2,121	6,360	138	12,207	18,705	10	8,016	..	..	..	..	..
Hackney (Stoke Newington), N.	..	1	47	76	5	17	..	..	86	..	..	..	..	1	177	77	0	107	1	½	3,000	1,500	500	31,000	33,000	7	..	6,550	..	..	6,500	..
Hampstead, N.	..	4	175	34	5	140	..	1	156	..	..	..	..	..	..	35	4	31	6 men constantly, say 4 times	½	2,100	4,200	Contracted for	Contracted for	4,200	2	7,196	..	1,152	..	896	..
Holborn, N.	8	4	197	..	2	86	..	1	168	..	2	129	..	..	..	9	3	140	12	½	648	3,888	171	7,300	11,359	4	..	300	..	..	..	..
Islington, N.	9	1	31	99	0	36	..	..	..	..	..	..	..	2	11	108	3	78	6	⅓	2,918	5,838	..	23,850	29,688	8	5,565	..	2,355	..	7,183 5,786	..
Kensington, N.	4	3	163	74	4	102	..	..	207	..	6	0	..	..	..	79	7	32	6	⅓	4,576	7,150	Flushed away	25,500	32,650	6	9,683	..	9,673	..	..	..
Lambeth, S.	2	1	123	118	4	47	..	..	176	..	..	..	1	1	38	121	7	164	1	1	6,300	6,300	88	41,950	48,338	..	7,385	..	7,000	..	9,000	..
Lewisham, S.	..	..	..	51	3	212	..	..	..	..	..	..	..	..	..	51	3	212	Frequently	¾	2,000	1,500	186	13,714	15,400	6	13,976	..	..	..	..	..
Limehouse, N.	12	0	208	8	4	192	..	..	50	..	..	50	..	..	106	20	6	166	Frequently	1	790	1,350	210	13,500	15,060	2	..	400	..	..	..	..
Mile End, N.	4	4	104	28	4	171	..	..	..	..	..	..	..	..	..	33	1	55	12 in main thoroughfares, 4 in back, do.	⅔	1,250	215	125	12,400	12,740	4	..	2,500	..	..	..	..
Newington, S.	3	5	192	27	6	219	..	2	169	..	1	114	..	..	..	32	1	34	Frequently	¾	1,964	1,750	..	19,003	20,753	5	1,500	..	3,000	..	..	..
Paddington, N.	6	0	152	37	2	16	..	..	..	..	1	1	..	..	..	43	3	169	Frequently	1/13	2,552	1,768	243	26,383	28,394	5	..	11,135	..	..	..	..
Plumstead, S.	..	..	..	45	2	53	..	..	..	..	..	..	..	..	..	45	2	53	6	1	941	5,646	200	5,000	10,846	When required	..	5,000	..	..	..	..
Ditto Eltham.	..	..	..	17	0	0	..	..	..	..	..	..	..	..	..	17	0	0	12	1⅓	20	324	..	2,300	2,624	None	..	3,000	..	..	..	..
Poplar, N.	2	5	5	43	4	58	..	..	..	..	..	181	..	4	120	46	6	144	3	½	1,585	2,376	707	12,297	15,380	6	..	3,944	..	..	..	..
Rotherhithe, S.	3	7	60	9	5	211	..	..	63	..	..	..	..	6	174	14	4	68	6	1 and 2	600	Sewers & Gullies	543	7,500	8,043	7	1,000	..	..	..	..	..
St. George's-in-the-East, N.	10	6	52	2	4	38	..	..	76	..	..	70	..	..	..	13	3	16	Frequently	⅓	520	692	157	7,300	8,149	..	351	..	..	..	..	..
St. George's, Hanover Square, N.	8	0	161	30	6	81	..	..	40	2	2	2	..	..	..	41	1	64	Frequently	2	No information		1,000	30,000	31,000	8	..	12,000	8,000	..	2,000	..
St. George the Martyr, Southwark, S.	3	3	108	10	4	22	..	..	..	..	..	..	..	..	..	13	7	130	3	¼	800	600	300	8,800	9,700	6	..	2,600	..	..	..	..
St. Giles's, N.	12	4	193	2	1	131	1	1	174	..	1	99	..	..	..	16	1	157	Frequently	⅕	406	450	6	11,000	11,456	5	..	1,250	..	..	200	..
St. James's, Westminster, N.	5	6	186	4	0	35	..	..	..	..	1	200	..	2	119	10	3	100	Frequently	1	267	265	30	9,699	9,994	3	..	4,000	..	..	..	..
St. Luke, Middlesex, N.	11	0	149	1	1	173	..	..	..	..	3	10	2	3	162	15	1	54	Frequently	½	280	250	225	5,200	5,675	4	200	..	..	..	..	..
St. Martin-in-the-Fields, N.	4	4	45	1	1	188	..	..	83	..	5	40	..	..	..	6	3	136	36	½	430	7,740	40 to 50	6,000	13,790	3	567	..	..	..	312	..
St. Marylebone, N.	22	0	65	40	7	13	..	..	..	..	6	147	1	4	58	65	2	63	6	¼	2,000	3,000	180	24,000	27,180	7	..	9,000	..	..	..	2,000
St. Olave, S.	5	3	175	..	..	125	..	..	..	..	..	177	..	3	88	6	0	125	12	⅓	271	1,080	218	4,700	5,998	3	..	10	..	..	..	..
St. Pancras, N.	19	0	211	58	3	164	..	..	183	..	4	31	1	3	150	79	5	79	Frequently	..	No Record	..	83	45,000	45,083	9	..	7,100 400 Kentish Rag	..	..	..	..
St. Saviour, S.	7	2	140	2	0	211	..	..	150	..	1	167	..	..	..	9	6	8	12	1	455	5,460	25	9,000	14,485	2	100	..	..	..	..	..
Shoreditch, N.	14	1	99	24	5	208	..	..	39	..	..	87	3	0	196	42	0	189	12	½	2,100	12,600	400	Contracted for	13,000	5	2,409	..	1,263	..	162	..
Wandsworth, S.	..	..	..	28	1	128	..	..	..	..	..	..	..	..	..	28	1	128	4 to 6	¾	600	2,250	7	8,000	10,257	2	..	2,600	..	..	2,770	..
Battersea, S.	..	4	138	46	6	115	..	..	..	..	..	..	..	1	120	47	4	153	14	½	2,065	14,455	66	11,000	25,521	4	5,281	..	..	..	..	..
Clapham, S.	..	..	..	24	2	203	..	..	..	..	..	..	..	..	..	24	2	203	3	¾	1,130	1,000	100	7,500	8,600	..	..	3,000	..	..	..	..
Putney, S.	..	..	..	25	3	71	..	..	..	..	..	..	..	..	..	25	3	71	Frequently	¾	648	890	168	3,043	4,101	2	2,000	..	2,700	..	..	..
Streatham and Tooting, S.	..	..	..	37	3	32	..	..	..	..	..	..	..	..	..	37	3	32	4 to 10	⅔	1,600	7,462	60	6,000	13,522	4	3,000	..	7,000	..	1,000	..
Westminster, N.	5	1	0	13	3	41	..	..	..	..	..	..	2	4	45	21	0	86	Frequently	½	700	1,400	300	16,600	18,300	8	6,107	..	1,619	..	..	..
Whitechapel, N.	19	7	85	..	..	..	..	..	..	..	1	53	..	..	..	20	0	138	Frequently	3'0" × 2'0" × 3'6" 21 ft.	No record	..	Very considerable quantity	8,693	8,693	12	..	..	..	..	..	..
Woolwich, S.	1	0	67	17	0	0	..	..	219	..	..	..	..	..	..	19	7	107	Various times	½	320	640	Very few	2,717	3,357	3	..	1,000	..	..	..	..
Ditto North, N.	..	..	..	1	6	41	..	..	..	..	..	..	..	..	..																	
Fulham, N.	..	..	167	48	7	135	..	2	210	..	1	63	..	1	47	49	5	182	4	⅓	3,185	4,248	No record	20,589	24,837	10	5,851	..	..	..	..	..
Clerkenwell, N.	19	..	..	..	..	..	..	..	..	..	..	..	..	..	..	19	..	..			700	1,400	300	16,000	17,700	8	..	..	..	..	..	..
Strand, N.	8	6	7	..	1	3	..	1	27	..	..	216	..	..	..	9	1	33			260	260	100	9,000	9,360	3	..	..	..	..	..	..
	284	3	139	1,329	6	133	9	5	14	14	0	197	32	3	83	1,670	3	126			62,989	143,704	8,233* 6,387 5,700 20,320	603,192	755,129 6,387 5,700 767,216=882,298 Tons	224 †	90,279 =	85,289 103,820	59,262 =	.. 68,151	35,809 =	2,000 48,342 50,342
																											Granite Flints . Hoggin	189,109 68,151 50,342 307,602 Tons				

* 8,233
6,387 S. } Main Lines
5,700 N. } Sewers.
20,320

† 224
125 M. B. W. Flushers.
349

[*To face p.* 16.

quantity of material, broken granite, broken flint, and hoggin, used in maintaining the roadways.

From this table it appears that there was, in 1878, the length of about 1670½ miles of roads and streets in the Metropolis, of which there were in round numbers—

	Miles.		Per cent.
Granite pavement . . .	284½	or	17
Macadam and gravel . . .	1330	,,	79·6
Asphalte	9½	,,	0·6
Wood	14	,,	0·8
Flagging	32½	,,	2·0
Total length . . .	1670½	,,	100

Since the date of this statement, wood paving has been considerably extended in some of the principal thoroughfares. The quantities of refuse collected from the catchpits, drains and streets in the same year, were as follows :—

Year 1878.		Cubic yards.
Mud and dirt removed off roads, streets, etc. .		603,192
Deposit removed from sewers :—		
Local sewers	8,233	
Main line sewers	12,087	
		20,320
Deposit intercepted by, and removed from catchpits		143,704
Total (882,298 tons) . . .		767,216

The quantity of refuse removed off the roads, streets, and alleys, averages 361 cubic yards per mile of way for the year. It may well be imagined that the maximum rate of accumulation and removal of refuse is something very much beyond the average rate. On London Bridge, for instance, it has already been stated that the collection of refuse, without the contingency of escaped house-refuse, averages from three to three-and-a-half cubic yards per day, which, if reckoned up, represent accumulations of 8000 cubic yards per year per mile of length, taking the length of the bridge at 261 yards. In the City of London, from 48 miles of streets, 30,000 cubic yards of slop were collected in the year 1879–80, being at the rate of 625 cubic yards per mile of street. In Newington, as a contrast, 60 cubic yards per mile was the rate of slop-lifting.

The gross quantities of material used, in 1878, for maintaining the streets and roads of the Metropolis were :—

	Cubic yards.
Broken granite	164,444
Broken flint	59,262
Hoggin	50,619
Total used	274,325

This quantity bears a very high ratio to the volume of slop and deposit lifted during the same year, already stated to be 767,216 cubic yards. It is 36 per cent., or more than one-third of the volume lifted, that is to say, the volume of slop and deposit together is scarcely three times the volume of the material from which it is produced. But it is necessary, in order to form a closer comparison, to take the solid volume of the broken material, which is, say, one-half of the volume in bulk, which then becomes more than one-sixth of the volume of slop and deposit. This proportion, still very high, and not encouraging from the manurial point of view, is due to the great preponderance of macadam and gravel in the construction of the streets, amounting to four-fifths of the entire length of way.

DOMESTIC REFUSE.

In addition to the "slop," as it is called, comprising, when the word is used in a general sense, the road and street refuse, wet or dry, the "dust" or domestic refuse is to be estimated. The following tabulated returns from five metropolitan parishes, showing the loads or cubic yards of dust in comparison with the loads of slop, in recent years, afford probably a means of forming a fair average proportion of "dust" to "slop :—

	Cartloads of Dust.	Cartloads of Slop.	Total Cartloads.	Street Mileage.	Cartloads per mile.
Islington . . .	28,113	22,230	50,343	98	514
Chelsea. . . .	8,615	9,473	18,088	32	565
Paddington . .	16,830	26,380	43,213	43	1005
St. Pancras . .	25,000	45,000	70,000	80	874
City of London .	27,000	30,000	57,000	48	1188
Totals . .	105,558	133,086	238,644	301	793
Averages per Mile	351	442	793		

The average quantity of slop in these five parishes is shown to amount to 442 cartloads or cubic yards per year per mile of way. The gross average quantity for the whole of the Metropolis is, as already stated, 361 cubic yards per year per mile; and the probable corresponding quantity of "dust" or house-refuse may be estimated by the rule of three. If the average quantity of dust produced by the five tabulated parishes, 351 loads, be reduced in the ratio of 442 cubic yards to 361 cubic yards, the resultant quantity 1351 $\times \frac{361}{442} =$ 1287 cubic yards is the gross average of "dust" or house-refuse per year per mile of way. Multiplied by the total length of way in the Metropolis, $1670\frac{1}{2}$ miles, the estimated quantity of house-refuse becomes $(287 \times 1670\frac{1}{2}) =$ 479,434 cubic yards per year. The respective quantities of slop, deposit, and dust collected in the year 1878, may, from the foregoing data, be estimated as in the following table:—

STREET AND HOUSE REFUSE IN THE METROPOLIS, 1878.

Refuse.	Total for the Year.	Per Mile of Way.	Per Mile per Day.
	cubic yards.	cubic yards.	cubic yards.
Slop.	603,192	361	1
Deposits in catchpits and sewers.	164,024	98	$\frac{1}{4}$
Slop and deposits . . .	767,216	459	$1\frac{1}{4}$
Dust or house refuse . . .	479,434	287	$\frac{3}{4}$
Totals	1,246,650	746	2

The magnitude of the work of removal of street and house refuse is here made apparent :—1,250,000 cubic yards for the year ; daily, 3,416 cubic yards ; 2 cubic yards for each mile every day. The dust or house-refuse is three-fourths as much as the slop from the surface of the street ; and the stuff which flows into the gullies is one-fourth as much as the slop which remains on the surface, or it is one-fifth of the whole of the refuse generated in the public ways. The considerable proportion of matter thus withdrawn from the surface by natural gravitation, and settled in the catchpits and sewers, is evidence of the evil of infrequent cleansing of the road surface ; for so large a proportion thus withdrawn from the reach of shovel and broom to fester unseen, could only have been translated beneath the grid as a result of avoidable accumulation at the surface. A few instances from the table may serve to illustrate the question. In the City of London, paved entirely with granite, asphalte, wood, and flagging, of the 33,272 loads of slop and deposit removed, 3272 loads were taken from the catchpits and sewers,—about 10 per cent. of the whole quantity. In the parish of Chelsea, in which the streets are laid almost entirely with macadam, of the 18,840 loads of slop and deposit removed, 8040 loads were lifted from the catchpits and sewers, being 42 per cent. of the whole quantity removed. To what extent this enormous and illegitimate precipitation of refuse underground was avoidable, it is impossible accurately to estimate ; but evidently much of it, at all events, is attributable to the character of the way, and it supplies a powerful argument in favour of frequent thorough cleansing of the street surface.

STREET CROSSINGS.

A part of the street surface of great cities not usually attended to with due regard to the comfort and convenience of the public is that comprised in crossings.

The Metropolis Management Act, 1855, empowers vestries and other local authorities in the Metropolis to appoint crossing-sweepers by the following provision :—

> It shall be lawful for every Vestry and District Board to appoint and pay, or for two or more Vestries and District Boards to unite, when necessary, in appointing and paying suitable persons to cleanse and sweep, and to keep properly cleansed and swept daily, crossings for passengers over the streets and thoroughfares within their respective jurisdictions, and in such situations as the said Vestries or District Boards may from time to time fix and determine, which persons so appointed shall be distinguished by their dress or some distinctive mark as public servants.

It is a curious fact that although many complaints are constantly made of the objectionable characteristics of the semi-beggars who infest many crossings in all parts of the Metropolis, and of the unswept condition of other crossings in public thoroughfares of considerable traffic, no local authority has yet thought it expedient to put in operation this provision of the Act, by which many a respectable person might be placed in a position to earn sufficient to maintain himself and family in comfort, without any assistance from direct parochial relief.

A person so appointed would, by civil behaviour and proper attention, soon become the recipient of regular though perhaps small contributions from pedestrians frequently passing, who would willingly and gratefully recognise the comfort and cleanliness of a well-swept crossing, and others would perchance generously appreciate the difference between the respectable though humble crossing-sweeper, and the insolent rough, who, in the absence of alms, indulges in whining appeals for pence, or in foul-mouthed abuse and persistent entreaties.

"A MAN'S A MAN FOR A' THAT."

There are, however, among the crossing-sweepers, even under the existing haphazard and no-system, many not to be entirely reprobated.

The man who sweeps an ordinary crossing has safe, straightforward work to do. The man who undertakes the crossings at the intersection of great-traffic carriage-ways, has often a difficult and dangerous piece of work to perform, especially where the intersections are not at right angles and directly opposite, or where diagonal intersections converge.

This man, if skilful in "doing a little bit of fancy work round a corner," regards himself as much an artist as he who chalks blue seas, green moons and neutral portraits on the footway flagging, and the pride of skill is even to be found in the humble "scoopman," who ladles up liquid mud, and with a clever, ingenious but unregarded turn of wrist drops it into the cart without scattering a single splash upon the garments of the passers-by, and who would scorn the clumsiness of

> " Dick the scavenger [who] with equal grace
> Flits from his cart the mud in Walpole's face."

In the definition already quoted, Johnson recognised the fact that the humblest labourer in authority in the all-important work of cleansing and keeping clean thoroughfares of a great hive of civilized life was an entity of some importance.

As the more exalted classes should be expected to act up to the principles of the proverb—

> " Noblesse oblige "—

so may the small magistrate take to himself, and live up to, the principles enunciated in the couplet :—

> " Honour or shame from no condition rise,
> Act well your part—for there true honour lies " ;

and may with proper complacency reflect that he may be the more honest, straightforward man, although he has to remove the broken pie-dishes of a Premier, or the cast-off buttonholes of a Home Secretary.

DRINKING FOUNTAINS.

In the streets of the Metropolis, as in other great cities, it may also be remarked that other opportunities exist for enabling many disabled, but respectable persons, to obtain subsistence without recourse to parochial relief, in connection with the Drinking Fountains scattered over the Metropolis by the philanthropic efforts of the Metropolitan Drinking Fountains and Cattle Trough Association, and and by other agencies in the provinces.

The benefit of these admirable institutions would be manifestly and immensely increased if arrangements were made for a respectable old person to be allowed to sit by the side of a drinking fountain with a small table and with some drinking glasses. Many persons would take advantage of a clean glass, who would otherwise pass by, objecting to allay their thirst from the public ladle. The attendant should not, of course, be allowed to assume anything like proprietorship of the fountain, and should be prohibited from making any charge. The voluntary contributions for the use of a clean glass would be something appreciable, notwithstanding the meanness that unfortunately so generally prevails in a highly civilized community.

UTILIZATION OF REFUSE.

In considering the question of the utilization of street and house refuse, it must be borne in mind that street-scrapings vary very much in character, depending upon the season of the year, and the nature of the carriage-ways. There are two processes for utilization generally adopted in large cities of England that, in default of more euphonious terms, may be described as the "shoot" process and the "sifting" process. The "shoot" process consists in removing the refuse by railway or by water, to be shot on some piece of waste ground. By this means land, which otherwise has little or no commercial value, is in time converted into land capable of producing garden or agricultural produce. It is from the augmented, or rather created, value of the land thus systematically made valuable, that profit can be expected, and when the time arrives for the treatment of this subject in a comprehensive and statesmanlike manner, such a scheme, could, for the Metropolis, be fully and advantageously developed by arrangement with railway authorities, and the construction of depôts, convenient sidings, and works contingent.

The "sifting" process for dust, or house-refuse, is in daily use in most metropolitan and other yards. It consists in riddling the dust through sieves, either by machinery or by hand. It is separated into "breeze," "ashes," iron and other metallic products, rags, white glass, black glass, bones, "hard core" (broken pottery, &c., suitable for the foundations of roads and streets), "soft core" (garbage) and sundry other matters. All these constituents, excepting the soft core, are saleable. The soft core is required either to be cremated or to be worked into manure to render it inoffensive and marketable. The cost of this process varies, but it is done by contract at rates averaging 10*d.* per load of 1¼ cubic yards of dust.

The following are approximately the cost and the price realised from the sifted refuse of Paddington parish, exclusive of the cost of cartage to the depôt, and general charges. The Paddington "dust" is considered to be the best procurable at West Drayton, whither it is conveyed by canal.

	Per ton.	
	s.	*d.*
Breeze and ashes sifting	1	3¾
Canal dues to West Drayton	1	2
Barge hire, and wages of bargee, etc. . . .	0	8
Total	3	1¾
Average price 2*s.* 9*d.* per chaldron, or 3*s.* 0¾*d.* per ton	3	0¾
Net cost of sifting breeze and ashes, and delivery at West Drayton.	0	1
Street-sweepings and slop:—		
Canal dues to West Drayton	0	7
Barge hire, and wages of bargee, etc. . .	0	8
Charge for shoot at West Drayton . . .	0	4
Total cost of disposing of street sweepings and slop.	1	7

The general question of the disposal of street and house refuse to the best advantage came recently under the consideration of the Vestry of St. Pancras, and the general results of the inquiry may be briefly recorded.

In St. Pancras, in which there are about 80 miles of carriage-way, the proportions of the several kinds of roadway are as follows:—

St. Pancras.

	miles.		per cent.
Granite pavement	19	or	23·8
Macadam and gravel	58½	,,	73·5
Asphalte	⅛	,,	0·2
Wood	½	,,	0·6
Flagging	1½	,,	1·9
Total length of way . .	79⅝	,,	100·0

These lengths do not differ very much in their proportion from those of the Metropolis taken as a whole, as already stated at page 17, and for the present purpose the statistical details of the street-refuse of St. Pancras parish may be adopted as typical of those of the Metropolis generally. It is shown above that the granite and other paved surface occupies nearly one-fourth of the way, and the macadam nearly three-fourths.

With respect to the different classes of material to be dealt with, it may be stated that the dust and slop together amount to 70,000 loads or cubic yards per year, which, according to carefully-prepared returns, is divisible into :—

	Loads or tons.
Road-sweepings or "slop"	45,000
Dust from the ashpits.	25,000
Together	70,000

The road-sweepings, varying in character, may be subdivided as follows, giving a fair approximation :—

	Loads or tons.
Sweepings from paved streets in dry weather .	9,000
Sweepings from macadamized streets in dry weather	18,000
Slop from the streets in wet weather . . .	18,000
Total sweepings and slop. . . .	45,000

SWEEPINGS FROM PAVED CARRIAGE-WAYS.

Dry sweepings from paved streets contain a large proportion, about 75 per cent., of horse-droppings, and it is found that they are saleable for top-dressing, when well dried, at a price of from 3*d.* to 7*d.* per ton, free of charge for railway or canal dues. By judicious manipulation the sweepings could be advantageously mixed with stable-manure, the commercial value of which is from 2*s.* to 5*s.* per ton, free of charges for transport.

Stable-refuse is a considerable item of town-refuse which has not yet been referred to. In the parish of St. Pancras, alone, it is estimated that at least 10,000 loads or tons of stable-refuse is produced annually, being upwards of 20 per cent. on the weight of the street-refuse. But it is to be borne in mind that this, the stable-refuse, belongs to the producer, and also that the authorities are not bound to remove it. It occasionally fetches a high price, and it would be a convenient medium by which to increase the value of the sweepings of paved streets. It has been estimated that about half the quantity produced, or 5000 tons per year, could be secured, free of any charge but the cost for cartage; and there appear to be about equal facilities in the western and northern markets for disposing of any quantity of pavement-sweepings and stable-manure to market-gardeners and others. The following estimate of the receipts from the sale of these items of refuse is based upon the results of careful enquiries. It is assumed that of the 9000 loads of dry pavement-refuse, one-half, or 4500 loads, are mixed with the 5000 loads of stable-refuse available free of charges. Cartage is estimated for transport to a convenient site at Paddington, or at Belle Isle:—

	£	*s.*	*d.*
Sale of 4500 cartloads or tons of dry pavement-sweepings, containing less than 75 per cent. of horse-droppings, at 5*d.* per ton . . .	93	15	0
Sale of 9500 cartloads or tons of a mixture of dry pavement sweepings (4500 tons), and stable-manure (5000 tons), containing about 75 per cent. of horse-droppings, at 3*s.* 6*d.* per ton	1712	10	0
	£1806	5	0
Less cost of cartage for 5000 cartloads of stable-manure at, say, 9*d.* per ton, on 1½ miles average distance for cartage . . .	187	5	0
	£1619	0	0

Total annual value of dry pavement-sweepings and stable-manure, say, £1600 per year.

SWEEPINGS FROM MACADAMIZED CARRIAGE-WAYS.

The sweepings from macadamized streets are of two classes: those of streets which are repaired with gravel or flints, and those of streets repaired with broken granite. Of the 18,000 loads of dry sweepings in St. Pancras, it is estimated that 3600 loads consist of gravel and flint, which can readily be disposed of to builders. As the whole of the uncovered building land in that particular parish is on a clay subsoil, sand suitable for building purposes and plastering is expensive, owing to the heavy cost of carriage from a distance. The gravel and flint sweepings would consequently be readily sold in the yard, when well dried and sifted, at from 2*s.* 6*d.* to 3*s.* per yard.

The sweepings and scrapings from granite macadam ways would be of less value; but they could be made available for the same purpose by a process of washing, by which a proportion of good sharp sand could be obtained, worth about 2*s.* 6*d.* per cubic yard; also a proportion of granite and gravel stones, valued at 6*s.* per cubic yard. The remainder, mixed with burnt "hard core" and sifted, would sell at about 1*s.* 3*d.* per cubic yard, the residuum mud being available as manure.

The slop removed from the streets in wet weather is, when first removed, a bulky and heavy item. Its constituents are essentially the same as the dry sweepings and scrapings, plus water.

The 18,000 cart-loads of slop, as estimated, may be subdivided in the following proportions:

Pavement slop	6,000
Macadam slop	12,000
	18,000

This slop contains fully 50 per cent. of water, which can be separated by partial drying on filter-beds, leaving but half the bulk to be dealt with.

The 6000 loads of pavement slop, when dried, can be mixed with the inferior dry pavement sweepings, and be so disposed of.

The 12,000 cart-loads of macadam slop can be passed through the wash mill—such as is employed in Islington parish, to be subsequently described—either when first received in the yard, or subsequently after deposit during heavy weather. By means of the wash mill the sand and stones are separated from finer matter, from which the water is strained off on filter-beds.

HOUSE REFUSE.

Having so far discussed the disposal of the street-refuse, there remains for consideration the "dust" or "house-refuse," of which there is an annual production of 25,000 loads in the parish of St. Pancras alone. For the utilization of the dust it requires to be sifted and sorted, for which the employment of a great number of hands is required, although, as an alternative, the sifting could be done more economically by machinery moved by steam-power. The products are estimated from data derived from the experience of the Paddington depôt wharves as follows :

"DUST."

	Tons.
Breeze, suitable for brick-making, 2450 chaldrons, or	9,898
Fine ash siftings, called by brickmakers "ashes" or "soil"	18,558
Hardcore, consisting of broken pottery, and suitable for road making	959
Old iron, tin, and other metallic products . .	2
Old boots, and sundry assorted articles . .	2
Rags	67
Black glass	81
White glass	16
Bones	31
Paper, straw, cabbage-leaves, etc., are known as soft core	1,636
Total "dust," 25,000 cartloads, averaging $1\frac{1}{4}$ tons each, or	31,250

The "breeze" and "ashes" or "soil" are the largest and most valuable products of the "dust," but they require, for the most part, a country market. It is assumed that the proceeds of the sale of breeze and soil would only cover the cost of manipulation and burning the surplus. A furnace should be erected for the purpose of consuming all soft core and such ashes as there may not be an immediate demand for. The ash from this furnace would, when sifted and mixed with washed macadam-sweepings, find a ready market at about 1*s.* 3*d.* per yard. It would be available for use with Moule's earth-closets. The "hard core," the third in magnitude of the non-perishable products of dust, can readily be utilized as a foundation in road making.

Against the estimated receipts, £1600, by the sale of stable manure and pavement sweepings, would have to be set off the estimated cost for cartage of 70,000 cartloads to a depôt at Paddington or Belle Isle, with other annual charges, amounting together to £6250, irrespective of general superintendence. There is also to be set off the annual cost of removing "slop" and "dust," which in the year 1879–80 amounted to £13,937 for the parish of St. Pancras, distributed thus:—

			£		*s.*	*d.*	
Cleansing	45,000	loads of "slop"	7750,	or	3	5·3	per load.
Dusting	25,000	loads of dust	6187	,,	4	11·4	,,
	70,000 loads.		13,937	,,	4	0	,,

From the foregoing estimates, the extreme difficulty of dealing with street and house-refuse of a *Huge Wen*, as the Metropolis has been aptly styled, on a commercial basis, or in any financial sense of making both ends meet, must become apparent. "Slop" and "dust" are not so acutely noxious as sewage, which has been described by Sir Joseph Bazalgette as "an enemy to be got rid of as quickly as possible." They are nevertheless persistently produced in the ordinary course of civilized nature, and must, like sewage, be got rid of, an imperative necessity, which overrules considerations of simple finance.

MANIPULATION OF REFUSE. ISLINGTON WASHING PROCESS.

The Islington Washing Process, already briefly alluded to, is in operation in one of the yards of the Islington vestry at Holloway. The Wash Mill is a medium for washing the slop and macadam-sweepings, as in a pug-mill, agitated by revolving stirrers. The liquid is subsequently poured on carefully prepared filter-beds, from which the water is passed off perfectly clear and free from the mud, which is left as a deposit on the surface of the filter-bed, whilst the sand and stones are left behind at the bottom of the mill. This mill is worked by two horses. About 35 cubic yards of macadam slop is washed per day; producing about 14½ cubic yards of sand, and 3½ cubic yards of stones, at a cost estimated at 1*s*. 3½*d*. per cubic yard. The selling price in 1880 was 2*s*. 6*d*. per cubic yard for sand, and 6*s*. per cubic yard for stones, showing considerable margins of profit on the cost of washing. The mud refuse has a saleable value of 8*d*. per ton. It is of the nature of a very rich loamy sand, especially when mixed with burnt "dust," or burnt "hard-core" from the ashpits. The Islington vestry are to a large extent their own customers, as much of the manipulated products are made available for road-making.

A large washing machine, 36 feet in diameter, is also at work in a brick-yard, at White Hart Lane, on the Great Eastern Railway. It is driven by steam power, and it washes daily about 200 tons of chalk and brick earth.

Since 1880, the washing process has been carried on upon a more extended scale; about 125 cubic yards of slop is now washed per day, by means of three washing mills driven by a 12-horse-power steam-engine. The produce consists of 22 cubic yards of sand and ballast, of which the sand is sold for 3*s.* per cubic yard, and the ballast for 4*s.* The work as carried on results in the net loss of 2½*d.* per cubic yard; but as the cost to the vestry by the previous system of disposing of the slop is stated to have been 1*s.* per yard, relatively, a saving of 9½*d.* per cubic yard would appear to have been effected.

NEWINGTON PROCESS.

The Newington process of manipulating town-refuse, by which an artificial manure called "Newington mixture" is manufactured, bore the reputation of being the only system hitherto adopted in London that completely covers the entire annual outlay for scavenging. The vestry of St. Mary, Newington, has a receiving depôt, about 1¾ acres in area, adjacent to the railway, where breeze and ashes are manufactured, the railway arches being utilized for stables and stores. At the rear there is a large paved yard, constructed with gutter-drains, on which temporary banks are made in the shape of a hollow square of stable manure and soft core from the dust. Into this hollow square or temporary tank the slop and road-sweepings are shot from the carts as they are brought into the yard, until the tank is about half-filled. The water is allowed to drain off for six or eight days; after which the temporary tank is filled up with stable-manure mixed with soft core, and the whole is turned over, loaded into the railway waggons and conveyed to the country depôts, whence it is carted away by farmers, who, in 1880, paid 3*s.* per ton for the material in summer, and 2*s.* 9*d.* in winter. In Newington the proportion of paved to macadam carriage-ways is below the average, there being only 3¾ miles of the former to 27⅞ miles of the latter, in the ratio of about 1 to 7½.

There appeared, in 1880, to be hardly sufficient data for ascertaining the exact cost per ton of manufacturing the Newington mixture. It was stated that the entire cost of the depôt preparation and freight by railway was covered by the proceeds of the sale of this mixture, with that of breeze and ashes; whereas the cost of removing the refuse under contract, before the introduction of this system, was between £3000 and £4000 per annum for the removal of dust and slop.

Now, in 1884, Newington continues to dispose of its refuse manipulated on the same system. It has been found necessary to establish depôts in the country for surplus manure, one at Langfield and another at Meopham, at a cost of £4000. By the establishment of these depôts the vestry has been enabled to secure better prices for the manure—3*s.* 6*d.* per ton for nine months in the year, and 3*s.* per ton for three months. Orders are now booked three months in advance. It is alleged that the introduction of the treatment has resulted in a relative saving to the vestry of £27,000 in the course of ten years, although, according to the annexed estimates * for the financial year 1884–5, there would seem to be an actual excess of about £800 of expenditure over receipts.

The principal conditions for the successful practice of the Newington system would appear to be these:—

1. Cheap carriage from and to convenient depôts.
2. Poor stiff agricultural land for treatment easily accessible.
3. A moderate price for the mixture.
4. Scarcity and uncertainty in the supply of stable and other manures.

The results of the use of the Newington mixture in farming operations are stated to be very satisfactory. It is alleged that poor land in Kent, let at an annual rental of only 12*s.* per acre, has been made to yield, when treated with the Newington mixture, better crops than richer land commanding an annual rental of £5 per acre farmed in the ordinary way.

It is further stated that farmers using the mixture have been very successful in securing prizes for the produce at agricultural shows.

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* See pp. 34, 35.

ST. MARY,

DEPÔT DE

STATEMENT SHOWING PROBABLE RECEIPTS AND EXPENDITURE
AFTER BEING DEPOSITED IN THE DEPÔT,

Cr.	£.	s.	d.
Estimated amount to be realised by sale of 12,000 tons of mixture (summer supply), at 3*s.* 6*d.*	2100	0	0
Estimated amount to be realised by sale of 5000 tons of mixture (winter supply), at 3*s.* 3*d.*	812	10	0
Estimated amount to be realised by sale of 4000 tons of mixture (winter supply), at 3*s.*	600	0	0
Estimated amount to be realised by sale of 11,500 tons of ashes and breeze, at 4*s.*	2300	0	0
For removal of trade refuse	20	0	0
Meopham Depôt (surplus land)	5	0	0
*Balance against	803	17	11
	6641	7	11

NOTE.

Aggregate of Mixture.

Summer supply	12,000
Winter supply	5000
" "	4000
	21,000 tons.

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* This balance is £47 8*s.* 9*d.* less than that of the preceding

NEWINGTON.

PARTMENT.

ATTENDING THE DISPOSAL OF ROAD SWEEPINGS AND HOUSE DUST, FOR THE YEAR ENDING LADY-DAY, 1885.

Dr.	£.	s.	d.
Spreading, mixing, and loading 21,000 tons of mixture, at 4*d*.	350	0	0
Sifting dust, 13,500 loads, at 11*d*.	618	15	0
Loading ashes and breeze, 11,500 tons, at 3*d*.	143	15	0
Horses employed in loading (3⅓)	166	13	4
Railway carriage of 21,000 tons of mixture, at 1*s*. 8*d*.	1750	0	0
Do. on 11,500 tons of ashes and breeze, at 1*s*. 8*d*.	958	6	8
Do. for hard core to shoot, 1500 tons, at 1*s*. 8*d*., including loading	125	0	0
Railway carriage for old mats to depôt, 200 tons, at 1*s*. 8*d*.	16	13	4
Loading 1500 tons of hard core, at 3*d*., and unloading at Longfield, at 2*s*. 3*d*. per truck	39	11	3
Loading 200 tons of old mats, at 4*d*., and unloading and burning at Longfield, at 2*s*. per truck	7	6	8
Commission on sales, and incidental expenses, 32,500 tons, at 3*d*.	406	5	0
Stable dung, 750 horses, at 2*d*. per horse per week	325	0	0
Do. 150 horses, at 1½*d*.	48	15	0
Do. collection of 8000 loads, at 9*d*. per load	300	0	0
Do. for horse hire, collecting (2⅔)	133	6	8
Wages of driver and men attending the lift, cleaning well, &c.	325	0	0
Salary of vestry clerk for supervision of town and country depôts	100	0	0
Salary of vestry clerk's assistant, including railway pass	146	0	0
Salary of superintendent (one-half)	75	0	0
Contribution towards wages of shunter	20	0	0
Advertising sale of mixture and ashes	26	0	0
Rent of Meopham Depôt	15	0	0
Coals, coke, and firewood	145	0	0
Water (one-third)	25	0	0
Gas (one-fourth)	25	0	0
Oil, packing, boiler composition, &c.	35	0	0
Disinfectants	30	0	0
Shovels, dust baskets, sieves, &c.	50	0	0
Repairs to machinery	25	0	0
Rope, brooms, &c.	10	0	0
Contingencies	200	0	0
	£6641	7	11

year, notwithstanding an increased expenditure of £860 1*s*. 3*d*.

CITY OF LONDON. LETT'S WHARF.

The refuse of the CITY OF LONDON is of a more varied description than that of the metropolitan parishes generally, and receives systematic treatment at Lett's Wharf, on the southern side of the river near to Waterloo Bridge, about 1090 yards from the northern end of Blackfriars Bridge, and 2658 yards from Guildhall, about the centre of the City area. It was first used by the Commissioners of Sewers in 1869, but it had been for a long period used as a scavenger's depôt. In 1875, the Commission purchased a thirty-four years' lease of the property, and, from the plans of Colonel Haywood, rearranged the entire area for the disposal of the City refuse. The area is about 9000 square yards; there is a river frontage of 209 feet, a jetty projecting 98 feet from the river-wall, and the use of two draw-docks. Five barges can lie alongside the jetty and wharf frontages at the same time. There are two good cart-entrances to the wharf from Commercial Road, stables and workshops, sheds, living-rooms, and various other structures have been built at a large cost. They were sufficiently advanced to be occupied in December, 1876. The stabling, for seventy-two horses, was divided into four compartments, each capable of accommodating eighteen horses; the space between the stables is a yard covered with a glass roof, so that horses can be groomed in all seasons under cover. Over the stables are lofts for the storage of hay and corn, a room for general stores, another for storing and repairing harness, a chaff store, and a chaff-cutting room, with steam-engine and machinery for cutting and cleaning the chaff, mixing it with corn, and delivering it at the level of the stables for consumption.

On the eastern side of the stabling, separated from it by a roadway twenty feet wide, there is a range of buildings, comprising stabling with five loose-boxes and means for mashing and steaming food, and applying hot and cold water to sick horses; a blacksmith's forge, a boiler-house for supplying steam to the chaff-cuttting machine, a scavengers' mess-room ; a kitchen for the cooking of food, and a chamber heated by steam for drying clothes, horse-cloths, and other conveniences.

Nearer to the river, and close to those parts of the wharf upon which dust and ashes are deposited, there are rooms for the accommodation of the hands employed in the dust-yard, those for the men being on the eastern side, those for the women on the western side of the wharf. On each side of the wharf is a store for rags, paper, iron and other materials, products of the manipulation of the "Dust."

Near the river there is a furnace, with a shaft 120 feet high, for consuming old baskets, matting and like materials.

The refuse of the City of London is classified by Colonel Haywood under five heads.

1. House-refuse.
2. Trade-refuse.
3. Market-refuse (both animal and vegetable).
4. Street-sweepings.
5. Condemned meat.

All of these, with the exception of the 5th item, are conveyed to Lett's Wharf—the meat condemned by the Medical Officer of Health being sent to, and treated at another place.

House-refuse consists mainly of ashes, cinders, paper, rags, broken crockery, bones, a small quantity of vegetable matter, at times small quantities of human excreta, mixed with the ashes removed from the houses inhabited by the poor, in the few obscure courts and places still remaining in the City area.

Trade-refuse consists largely of coarse paper, string, straw, wood-shavings, sawdust, and various grasses used for packing goods and fruit. It comprises also engine-ashes, clinker, broken stoneware, broken glass, and brick rubbish. The refuse from fruiterers, eating-houses, and taverns, and fishmongers, is more or less in a wet state, generally mixed with considerable quantities of sawdust, and much of it may be classed with market-refuse. There is also a considerable quantity of spoiled tinned food.

Market-refuse is the animal and vegetable matter removed from the several markets, with similar refuse from fishmongers and others already mentioned. Many tons per week of bad shell-fish and wet fish are carted from Billingsgate Market to Lett's Wharf.

Street-sweepings are the materials removed from the public ways, consisting largely of horse-droppings, with hay, straw, fragments of packing materials, and other waste materials incident to the enormous trade and traffic. They include also the dust and litter illegally swept on the surface of the public ways out of shops, and deposits from the catchpits of gullies.

Condemned meat is first spoilt by immersion in a bath of chemical fluids, so as to render impossible its use for human food. The bath is in a separate building near to the Metropolitan Meat Market. The spoilt meat is sold to contractors, and is delivered at their yards by the Commissioners partly to Bow and partly to Belle Isle. The quantity of condemned meat amounted in 1880 to 273 tons, which was sold for £870.

The quantity of refuse from the City of London delivered at Lett's Wharf, increased from 50,054 loads in 1871 to 61,239 loads in 1880. The carts or vans vary from 1¼ to 2 cubic yards in capacity; they are not always filled, and it is estimated that a load represents the average of one ton weight. The refuse removed in 1880 was :

	Loads.
House, trade and market refuse . .	31,161
Street sweepings and slop . . .	30,078
Total loads	61,239

The stated number of loads of street-sweepings and slop does not appear to include the deposits taken from the gullies and sewers. These quantities may be taken at per mile of way (48 miles), and per day, for comparison with the general averages for the Metropolis given at page 19, as follows :

CITY OF LONDON, 1880.

Refuse.	Total for the Year.	Per Mile of Way.	Per Mile per Day.
	cubic yards.	cubic yards.	cubic yards.
Slop and street-sweepings . . .	30,078	627	1·72
House, trade, and market refuse .	31,161	649	1·78
Together	61,239	1276	3·50

The house, trade, and market-refuse together, equal the slop and street-sweepings. The total refuse is generated at the rate of 3½ cubic yards per mile of street per day, as compared with 2 cubic yards for the Metropolis as a whole.

When the "dust" carts arrive at the wharf, their contents are tipped into heaps at the places most convenient for the people who are employed as sorters. Some 70 persons, chiefly women, are engaged in this work. Most of these are paid piece-work, but 16 female sifters receive 7 shillings and a little coal and wood weekly. Standing in the midst of fine dust piled up to their waists, with face and upper extremities begrimed with refuse, they are surrounded by and breathe a foul, moist, warm atmosphere.

The dust is placed in large circular sieves, which are worked by the sifters, and divided by the process into two portions, the finer of which falls at the feet of the operators, partly burying them, and the coarser, which is thrown on one side for the next process. This is the separation and sorting of the various articles, all of which have a certain commercial value, such as clinkers, bottles, old metal, crockery, paper, corks, bones, rags, string and so on, which are carefully placed in distinctive heaps for sale. The sifters and sorters are employed by a general contractor, who is paid by the Commissioners some 9*d.* per load, the contractor taking as well the paper, whole bottles, rags, iron, tin, etc., leaving to the Commissioners the breeze, soft core, and useless hard core (worn-out pots and pans and large articles). This payment of 9*d.* a load amounts to from £20 to £25 per week. The following are some of the more constant products, with the approximate market values attached :

Scraps of iron	25*s.* to 30*s.* per ton.
Rags	20*s.* ,,
Bones	50*s.* ,,
Iron	20*s.* ,,
Metal	18*s.* per cwt.
Tin ware	3*s.* per cart load.
Corks	1*s.* per bushel.
Bottles (whole)	9*d.* per gross.

It is generally understood that "crinoline steel" is about the only article found among the refuse that can neither be utilized, converted, or easily destroyed.

Barges are loaded with the "breeze" and "ashes" in the proportion of 1 to 2, and sold to brick-makers. A barge load varies from 60 to 70 chaldrons. The hard core (clinkers, broken bottles and crockery) is used for road-making.

The value of breeze and ashes varies; latterly it was from 2*s.* to 2*s.* 6*d.* per chaldron. The Commissioners have frequently to pay 50*s.* a barge-load for the removal of the hard core. About one barge-load per week is thus disposed of.

The expenses incurred in the work comprise charges for

A general manager and salesman at £225 per year;

A gauger at 50*s.* per week ;

Twelve men at 5*d.* per hour, day work, or 3*d.* per chaldron for stuff shot into barges ;

A lighterman, to look after the barges and berth them, at 35*s.* per week, with a house ;

A furnace man at 4*d.* per hour, 10 hours a day.

These charges are irrespective of the general staff of the yard and those employed outside its walls.

The horse-manure collected by the street-orderly boys in the highways of the City of London, and brought to

Lett's Wharf, is mixed, upon a platform on the open wharf, with soft core, slop, offal, and decaying fish, &c. The mixture is sold at certain seasons to farmers at £2 per barge-load of 40 tons. The reason offered for this extraordinary and apparently unthrifty sophistication is that it facilitates the disposal of malodorous material, for which, in its offensive integrity, there would be no direct market.

The ordinary street-sweepings or mud are disposed of in conjunction with animal and vegetable refuse. Market-refuse is, when collected, at once mixed with the sweepings when they are dry or nearly so, and shot from the carts into barges which are always lying ready, and daily leave the wharf with this mixed material. It is but rarely that any offensive matter remains at the wharf twenty-four hours.

Street-sweepings, when in large quantities in the condition of very diluted slop, are not at all times shot directly into the barges; but occasionally deposited on the wharf, temporarily mixed with straw litter and dry material. Water rapidly drains away, and the residue is mixed with the dry sweepings, stable manure, or other drier matters having manurial value, and cast into the barges.

Materials liable to decompose or become offensive are not removed from the wharf through the public streets; old iron, tin, lead, glass, leather, paper, and other hard materials alone being carted away. Nearly all this refuse material is sold, some being almost given away, and it is only at rare times that the Commission has to pay for getting rid of the material not burnt up. In the furnace are destroyed all baskets, matting, shavings, and other refuse which would be injurious to the sale of the street-sweepings and market-refuse, if mixed with them.

The refuse thus sorted and sifted commands a steady sale, the proceeds of which, after covering the cost of sorting, sifting, and removal, leave a balance of gain over the expenditure. The following return, compiled by Colonel Haywood, shows what has been obtained by the sale of the refuse delivered at the wharf, and the expense incurred in manipulating and disposing of it, for a period of four years :—

REPORT OF THE CITY OF LONDON. SALES.

Year.	Receipts.									Expenditure in Sorting, Sifting and Removal.			Balance Receipts over Expenditure.		
	Sale of Manure.			Sale of Ashes and selected Materials.			Total.								
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
1876–77	2416	16	4	3147	7	0	5564	3	4	3197	15	9	2366	7	7
1877–78	2245	6	0	4247	17	6	6493	3	6	3597	10	2	2895	13	4
1878–79	1999	17	0	4376	19	3	6376	16	3	3338	5	5	3038	10	10
1879–80	1015	0	0	2575	17	9	3590	17	9	3114	1	9	476	16	0
Average for 4 years, 1877-1880.	1919	4	10	3587	0	4	5506	5	2	3311	18	3	2194	6	11

None of the cost of collection in the City, or cartage to the wharf, of the material, is included under the head of expenditure in this table ; but the delivery on the wharf and the shipping are included.

Large works for the destruction of the refuse of the City of London, on Fryer's principle, are now in course of erection at Lett's Wharf. An account of these works will be given in continuation of a general account of Fryer's system further on.

MANURE COLLECTED BY STREET ORDERLIES.

It is greatly to be regretted that the material collected by the street-orderlies is not more carefully treated and kept separate and unadulterated, so as to induce some enterprising agriculturists to turn attention to the utilization of the peculiar fertilizing qualities it must possess. The supply would be sufficient for the production of practically unlimited quantities of Mushrooms, Scotch bonnets, and Champignons, for which there would always be unlimited demand.

The result might be as—if not much more—important to the agricultural interest as the suggested cultivation of fruit for conversion to jam.

PROVINCIAL CITIES.

In the provincial cities, local conditions are materially different from those that "shape the course" of metropolitan authorities.

For towns which are situated on the coast, as Liverpool, such portions of the "dust" as after manipulation can be disposed of at a price,—iron, rags, glass for instance—are utilized, the stable-manure is sold, and the residuum is simply tipped into a steam hopper-barge, and taken to sea.

In inland towns that have no convenient outlet for water-carried sewage, and consequently adopt the "Pail system," the night-soil is usually worked into the dust and street-sweepings, to form artificial manure. This treatment has obtained principally in connection with the Rochdale Tub System, adopted in 1870; but it has been introduced at Manchester and Salford, and it had been employed in other forms for many years in Birmingham and other inland towns in the north.

The Goux process has been extensively combined with the Pail system. In the Goux process, animal, vegetable and fibrous matters are mixed with sulphate of iron, or sulphate of lime; and are made available in a manner somewhat similar to that adopted with Moule's earth-closet system. It has been practised in Sheffield, Salford, Aldershot camp, and Halifax; and extensively in the rural districts in the counties of Rutland, Buckingham, and Leicester.

From the evidence presented in the foregoing pages, it may be concluded that the principle of self-supporting industry, or of bringing about a balance at least of expenses and receipts, can find no considerable place in dealing with the question of the treatment and disposition of town-refuse. It has been found practicable in some cases to cover the cost of sifting and sorting house-refuse, by the proceeds of the sale of the classified articles. But these items do not bulk largely in the gross account, and the consideration of the best mode of dealing with the "refuse" of large and populous communities must be approached in a truly liberal and large-minded, far-seeing, catholic spirit—a spirit that will renounce "rigid economy" as parsimonious extravagance, and regard judicious and generous expenditure as true and genuine thrift, although the immediate estimated returns may not be regarded as satisfactory, viewed in the light of "dividend."

UTILIZATION OF STREET AND HOUSE REFUSE IN CONNECTION WITH SEWAGE.

"DIRT is matter in the wrong place,"—such was the epigrammatic dictum of Lord Palmerston some 30 years or more since. He was a Statesman who would not have hesitated to recommend the adoption of an extensive and well-considered plan for the removal of the fortuitous concourse of atoms from the wrong to a right place when the operation was of a nature widely and permanently to benefit his country, even if the process were not directly lucriferous—so as to eventuate in 5 per cent. per annum, or in a return immediately equivalent to 20*s*. to a £.

The reconversion of sewage into the profitable primary elements of which it is composed, remains a problem not yet satisfactorily solved. Many modes of treatment have been advanced, advocated, and essayed; but a comprehensive solution of the problem yet awaits adoption. Meanwhile the rivers and streams in this country are contaminated and poisoned by discharge from water-closets, which, however effective as a means of easily removing animal excreta from the dwelling-house, are as mischievously effective in lodging it where its presence should only be tolerated under protest. Intercepting sewers as a necessity followed the introduction of the water-closet system, in the Metropolis. The cost of the system startled the Metropolitan Board of Works a quarter of a century ago, and now the necessity for the extension of the main drainage lower down the river is becoming more and more urgent and apparent, and whilst there is yet time for the development of a matured, comprehensive scheme of extension, it is worthy of consideration whether a system of transport and deposition, on some extensive area of waste lands, of the street and house refuse, in combination with the discharge of the Metropolitan sewage, might not be effected with advantage ; the former by railway, the latter by culverts. There is at hand a scheme, brought forward in 1864, that of Messrs. Napier, Heenans, and Hope, for conveying the discharge of the section of the Metropolis north of the Thames to the Maplin Sands on the Essex coast. The dry-weather sewage was taken at 10 millions of cubic feet per day, subject of course to material increase. The main culvert for the extension was designed to start from Abbey Mills, three miles from London, with a duplicate section or branch from the Barking reservoir. These two culverts were to be united at a distance of 6 miles from Abbey Mills, and to be 10 feet in diameter for a length of 38 miles, to the head of the navigation of the river Crouch at Battle Bridge, the sewage following by gravitation to the sea. At the 28th mile, the conduit was to be again divided, the one branch leading towards the Maplin or Foulness Sands, and the other towards the Dengie Flats. The total distance from the Abbey Mills to the Maplin Sands is 44 miles. The scheme contemplated the reclamation of 7500 acres on the Maplin Sands and 4500 on the Dengie Flats, making together 12,000 acres. The estimated cost of culverts, pumping stations, and reclamation embankments and contingencies was £2,100,000, with an annual cost of £10,000 for pumping. The total expense of carrying the sewage from Abbey Mills to the sea, including 5 per cent. on the cost of the culverts, but exclusive of sea-embankments, was estimated not to exceed one-fifth of a penny per ton.

In connection with some such scheme as this, arrangements might be designed and organized for the conveyance of all the house and street refuse of the Metropolis, by and on a line or lines of railway constructed more or less in combination with the culvert running alongside or upon it. The cost of such railway double line, say 50 miles in length, at the rate of £20,000 per mile, would amount to £1,000,000. It was estimated that the house and street refuse amounted in round numbers to 1¼ millions loads or tons for the year 1878, say 1½ millions for 1884, equivalent to 4110 per day. If carried in 10-ton waggons, in trains of 40 waggons, making a train load of 400 tons of stuff, ten train loads per day would be taken to the seaside. Allowing for returning, empty waggons, and for waggons loading, unloading and spare, a stock of, say, 3000 waggons would be necessary, with 30 locomotives and tenders. The estimated approximate cost for way, works, terminal accommodation, and rolling stock, may be taken as follows :—

Way and works	£1,000,000
Terminal accommodation loading banks .	120,000
Rolling stock	400,000
	£1,520,000

Taken together, the estimated approximate capital cost of the combined scheme of transporting sewage and refuse to the Maplin Sands would amount to £3,620,000.

The solid refuse discharged on the flats might be saturated to any required extent with sewage, from which much of manurial value would be absorbed by the solid matter, whilst the surplus (filtered) fluid would be allowed to flow into the sea. The sewage would be vastly in excess of the solid refuse in point of volume. Such of the sewage as would not be required for saturating more or less the mass of house and street refuse, could safely be left to diffuse over those vast waste areas, and to deposit suspended matter before finally escaping into the sea. In course of time extensive grass-lands would be created, which, judging from the long-tested precedent of the Craigentinny meadows, near Edinburgh, and the more recent example of the Salt Water Lakes, Calcutta (crude though this example may seem to be), might fairly be expected to produce valuable and continuous crops of grass and other products—eventually the Cerealia.

It is not suggested that any such a comprehensive and gigantic project could be undertaken by private enterprise, or that it would be a "paying concern." It is merely an outline of a suggestion of how "refuse,"—much of it offensive in its nature—might be dealt with *en masse*, and converted to useful purpose.

If it be true that "the man who makes two blades of grass grow in place of one is a benefactor to his country"—the community that converts 12,000 acres of waste land into productive pasture, or arable, would be equally praiseworthy to a proportionate extent, by *creating* so many acres of the richest alluvial soil.

The matter must be considered from a much higher point of view than that of mere grovelling—commercial profit and loss.

Whatever the outlay might be, the whole would be expended in the employment of labour without even an infinitesimal fraction of the eleemosynary element, and without diminishing by so much as a single farthing the available wealth of the country. The expenditure of a million or two in the employment of labour to the East of London, extending over a few years, would not be injudicious even if a generation were to pass away before the 12,000 acres were all a smiling plain, and the 12,000 acres of productive land would be an appreciable addition to the available Wealth of the Nation.

A generation is but a fraction of the life of a Nation, and the beneficial results of such a work would last as long as the Nation itself.

Maplin Sands do not afford the solitary instance of extensive waste lands within reasonable distance of the Metropolis, and other large aggregations of "refuse-producing" populations. The conditions of each vary, each would require different treatment and varied works; in one particular all would be similar, that the greater part—if not indeed the whole—of the expenditure would be in the employment of labour, and none of that outlay would be lost to the Nation.

UTILIZATION BY DESTRUCTION AND CONVERSION.

Disregarding matters of detail, it becomes manifest that in many cases the ultimate solution is to be found in treating "refuse" as "the enemy to be got rid of"—in a mode somewhat analogous to the line of treatment that has been applied to sewage. It must be treated in the mass, in this case not with water, but subjected to the action of that all-decomposing and all-purifying element, fire. Cremation had been partially and tentatively employed at the furnace at Lett's Wharf, and elsewhere. But the dispositions for dealing with and sorting the mass of refuse in detail had been generally little more than elaborate trifling, and had often generated inevitable nuisance. It is, however, with some satisfaction that attention can be directed and consideration given to some such comprehensive system of treatment by Cremation and Carbonisation as that which has been practically applied by Mr. Alfred Fryer, of Nottingham, by means of specially-designed furnaces.

The system involves two processes.

1. The Destruction by fire of everything combustible in house and trade refuse, with the incineration of sundry mineral matter.

2. The separation of the vegetable from the animal and mineral matters, and its Conversion into charcoal.

The first process is effected in an apparatus or structure called a *Destructor ;* the second in a structure or apparatus called a *Carbonizer.* The system is in operation at Leeds, Bradford, Warrington and Manchester.

FRYER'S DESTRUCTOR AND CARBONIZER.

The Destructor is defined by Mr. Fryer, as "a form of furnace designed for the reduction by fire of substances that contain only a small portion of combustible material. As erected at Armley Road, Leeds, it represents externally a cubical mass of brickwork, about 22 feet wide by 24 feet deep and 12 feet in height, all well tied and bolted together with strong iron rods, which perforate the whole structure.

The top forms a perfectly flat platform, having an opening about 3 feet square over each cell, into which the refuse to be burnt is shot directly from the collecting carts. An oval-shaped service hole of larger dimensions is provided for the admission and destruction of infected beds, mattresses, bedding, and other bulky articles. In direct continuity with this platform, is an inclined roadway, up which the carts laden with refuse travel. This need only be of sufficient width to enable carts to pass on their journeys up and down the incline. It terminates at the upper end in a level portion, about 3 or 4 feet higher than the top of the Destructor, so that the carts can back to and against a strong wooden baulk, or curb, and shoot their contents directly on to the mouths, or feeding inlets of the furnaces, without any further manipulation than the act of tipping or tilting. In this way an enormous amount of labour is saved, and the nuisance created by any process of sifting and sorting altogether prevented.

Internally the Destructor consists of a double set of three cells placed back to back, or in all 6 compartments, each of which is in direct communication with a tall chimney shaft. A cell, therefore, constitutes a separate furnace, being a cavity enclosed by a reverbatory arch, both being lined with fire-bricks. The cell is supplied with a hearth for the reception of the material to be consumed, from which it passes into the furnace proper; the fire-bars are placed in an acutely slanting position, in order to facilitate the passage of the heavier and indestructible portions of the refuse downwards to the front-doors, for the more easy removal of clinkers. These fire-bars are ingeniously made, representing in section an isosceles triangle, the base of which is placed upwards, so that when the burning refuse becomes sufficiently comminuted to pass through between the upper faces of the bars, the small ash falls into the receptacle below, and all chance of choking, the effect of which would be to diminish the draught, is obviated. These fire-bars are durable. At Armley Road they lasted more than 14 months, during which time over 15,000 tons of refuse had been burnt. Each cell has two openings in the reverbatory arch which correspond with the back end of the furnace. One of these is for the admission of the refuse as above described, and the other for the escape of the gaseous products of combustion into the flue. Between these openings is a brick wall, which constitutes a diaphragm which prevents the refuse as well as the gases having access to the flue. Each cell is also provided with an ordinary furnace frame and doors, of which the latter are required for two purposes—to start the furnace with fuel when commencing operations, and for the extraction, from time to time, of metallic articles (from a tea-kettle to a sardine box), and the clinkers which result from the burning refuse, containing every conceivable kind of indestructible waste. When the furnaces are in full work and constant operation the clinkers require to be withdrawn every two hours, and at about the same interval the attendant on the top of the Destructor shovels in a fresh charge.

One man suffices to feed six cells for the day working, but two are required for the night shift, most of the refuse being delivered after sunset. Each cell will consume seven tons of refuse in twenty-four hours; so that a Destructor containing six compartments suffices to consume 13,104 tons in fifty-two weeks of six working days.

A large quantity of superfluous heat necessarily results from the process, since the caloric is radiated from the reverbatory arch on to the burning material. The hot gases thus generated can be utilized on their way to the chimney shaft, and made to raise steam in a multitubular boiler of 6 feet in diameter and 10 feet in length, driving power being created at a pressure of 40 pounds to the square inch, and a temperature of 287·1° Fahrt. found to be equal to working two powerful mortar mills, with pans of 8 feet in diameter, by means of a horizontal engine of 14-horse-power with 12-inch cylinder and 2 feet stroke. It is alleged that the steam might be employed for concentrating liquid (in vacuo), however offensive, without the escape of any perceptible smell. It would be tedious and indeed unnecessary to enumerate or suggest the various purposes to which this vast motive agent could be applied in establishments of magnitude, an agent, be it remembered, obtained without expense after the first cost of boiler and gearing has been incurred.

The chimney shaft in connection with the Destructor forms a very important adjunct, and should be of sufficient height to prevent fine particles of dust being distributed over the neighbourhood. The chimney at Armley Road is 126 feet high, at Manchester it is 160 feet, at Bradford it is 180 feet high, at Birmingham it was originally 120 feet only, but it was found necessary to raise it to 170 feet, which height remedied all objections, and had the effect of materially increasing the power of the Destructor. Dust does not escape from the chimney, provided that the flues are large enough, and are not allowed to become choked with dust. They are made large in order to moderate the velocity of the current, and encourage the deposition of the dust, to be from time to time removed. By means of the Destructor the reduction of mixed matter is effected to the extent of from four-fifths to six-sevenths ; where six or seven loads of material more or less offensive had previously to be boated or carted away, only one load dessicated and inoffensive to be removed.

The formidable mass of vegetable refuse and garbage remains however to be treated by heat. Subjected to a high temperature in the " Carbonizer," these matters are in a manner distilled, the elementary gases, oxygen, hydrogen and nitrogen are driven off, and the solid residuum is charcoal.

The Carbonizer which is erected at Burmantofts consists of a group of vertical brickwork cells and furnaces, each cell having its own special furnace alongside. The structure is 26 feet long, 12 feet wide, and 15½ feet high, braced with iron rods and angle irons. The refuse to be carbonized is fed into each cell from the top. It is slowly carbonized as it descends, and the products—vegetable and animal charcoal—are withdrawn at the bottom. The interior of each cell is fitted with a series of alternating inclined or baffle plates of cast iron, which project from the walls of the cell, overlapping each other, and act as inclined planes, on which the matters slide downwards as consumed from one to another. The baffle plates are arranged in helical order, inducing a winding direction for the descent of the matters, by which they are turned over at each plate. The products of combustion of the fuel in the furnace—usually breeze—are conducted upwards, in the winding flue, underneath the baffle plates, passing laterally from under each plate, into the space under or behind the next plate above it. The plates, of course, become highly heated, and in that condition calorify, dry and ultimately carbonize the matters resting over them, which attain to red heat, as they arrive at the lower part of the cell—a chamber of red-hot firebrick. The charcoal which arrives at the hearth is withdrawn, at intervals of three hours, into a small truck, in which it is removed. The superincumbent mass sinks from plate to plate, and as it sinks it is exposed in its turn to the gradually augmenting temperature.

Air is not admitted to the cell during the process of charring. It is essential for the purpose that air should not be admitted. If it were allowed to enter, the charcoal would be consumed, contrary to the intention of the design of the Carbonizer, that being the production of charcoal bearing an appreciable market value.

The heated gases pass out of the cell through an opening near the top into a descending flue, from the lower part of which they are conducted by a horizontal flue to the chimney shaft. By this disposition of flues, economy of heat is maintained, as whilst the less heated portions of the gases have a tendency to descend, the more heated portions, on the contrary, tend to remain in the upper part of the descending flue.

The charcoal is red-hot as it is drawn from the cell, and is cooled in a charcoal cooler, by being passed through a revolving cylinder, over which cold water is continually streaming. It is sifted as it issues from the furnaces cylinder.

Each cell is capable of carbonizing 2½ tons of refuse in the course of twenty-four hours. The fuel required for the furnaces is sifted from the refuse of dry ashpits.

AT LEEDS.

Armley Road Station, the Destructor at which has above been described, is one of two stations at which the Corporation of Leeds carries on the process of burning refuse. It is situated in the town of Leeds, not more than a mile west of the centre of the town, in the midst of a dense population, surrounded by houses and shops of a respectable character. The refuse of about 60,000 persons is treated at this station. It was built in the year 1880, and has been in full operation since October of that year. The materials dealt with include house dust, street-sweepings, market refuse, and human excrement from middens, the pail system being in use in many parts of this district.

No offence is experienced in the vicinity of the depôts. The place is entirely free from smell, and although night soil in large quantities is mixed with the house refuse it is completely deodorized by the carbonaceous matter in the cinders.

Dr. W. Sedgewick Saunders, Medical Officer of Health for the City of London, describes the results of an official examination at Armley Road Station. "We saw the men," he says, "delivering large masses of refuse, including house dust, market refuse, and paved street sweepings, night soil from middens, &c., on the top of the Destructor ; then watched the gradual sinking of the stuff into the service holes, as the portions below were consumed; following this down to the front, we witnessed the extraction of the coarser materials (pots, pans, glass, crockery, &c.,) as well as the clinkers from the furnace doors below, the opening of which gave pretty hot evidence of the power expended in the cremation, without a grain of other fuel than that contained in the refuse itself; but the crucial test of all was when the smoke box, at the end of the boiler, through which all the fumes pass onwards to the chimney shaft, was opened, there was not the least odour, so completely had all organic matter been dissipated in the furnace. Again, when the clinkers and molten metal and glass, all fused together, were drawn, the only perceptible smell, and that very faint and momentary, was of a slightly sulphurous nature.

"The fine dust deposited in the flues and carried for some distance up the chimney by the gases and smoke, falls back into the 'dust chamber,' from whence it is removed when necessary and sold to farmers at 2*s.* 6*d.* per load. Large quantities of iron utensils, pots and pans, metal cases, tin, &c., fall to the front, and being raked out, and allowed to cool, sell for from 20*s.* to 30*s.* per ton."

A new commercial product of marketable value has been created by the use of the Destructor; that is the clinker resulting from the process of burning the refuse. It is ground by heavy rolling mills into powder, which when mixed with 25 per cent. of lime and a suitable proportion of water, is converted into a useful mortar or cement, found to be very tenacious and hard, from the oxide of iron and silicious matter derived from the clinkers: small hard bricks are also made from the same material. The making of this mortar costs 4*s.* 5¼*d.* per ton, inclusive of all labour and materials, and sells readily for 5*s.* to 5*s.* 6*d.* per ton; it will keep moist for forty-eight hours, and can be knocked up fresh for use when partially set, like any other mortar. It is valued by local builders, and much sought after. Each mill will turn out about 8 tons of mortar a day.

The other station in Leeds, the Beckett Street Depôt, is in the district of Burmantofts, about two miles from the centre of the borough, in a north-easterly direction. Here the Destructor and Carbonizer furnaces have been in constant operation for the last seven years. According to a report of Mr. Newhouse, the superintendent, in the month of December 1880, 782 loads of rubbish were destroyed at the Beckett Street Depôt, being at the average rate of 34 tons 3 cwt. per day for 25 working days; 31 tons of rubbish were used as fuel for the Carbonizer and 172 tons of market refuse was carbonized.

At the Armley Road Depôt, 1067 loads of rubbish have been destroyed, being an average of 45 tons 3 cwt. per day for 26 working days.

These two stations suffice for the manipulation and disposal of the bulk of the scavengering work of Leeds, covering an area of 21,600 acres, with a population of 326,000.

The following extract from the Report of the Sanitary Committee of the Council of the Borough of Leeds, showing the total cost of the works at Burmantofts, furnishes some useful information:—

"The Committee have fully examined into the cost of the apparatus at Burmantofts, and the quantity of material which has been dealt with, and submit to the Council the following figures and particulars with regard to the matter.

CAPITAL ACCOUNT.

	£	s.	d.
Cost of brickwork, engine, boiler, mortar-mill, destructor cells, carbonizer, and other apparatus and implements; making new road, and providing shed to cover apparatus, etc., etc., at the Burmantofts Depôt	4270	0	0
Royalty to patentee	150	0	0
Value of land and chimney shafts . .	1460	0	0
	£5880	0	0

REVENUE ACCOUNT.

EXPENDITURE.	£	s.	d.	RECEIPTS.	£	s.	d.
To Interest on £5880 at 4 per cent. . .	235	4	0	By Mortar . .	200	0	0
„ Sinking fund .	58	16	0	„ Charcoal .	100	0	0
„ Labour for 12 months . .	627	18	0	„ Scrap iron .	15	0	0
„ Lime . .	40	0	0		315	0	0
„ Depreciation at 5 per cent. covering repairs .	294	0	0	Balance .	990	18	0
„ Gas, water rates, etc. . . .	50	0	0				
	£1305	18	0		£1305	18	0

ESTIMATED QUANTITY OF MATERIAL DELIVERED AT THE DEPÔT.

	Tons.
Rubbish burnt in the Destructor	9923
Used in the Carbonizer for fuel	750
Market refuse	1800
Total	12,473

It will be observed that the net cost of dealing with 12,473 tons of rubbish and refuse delivered at the Burmantofts Depôt has been after the rate of £990 18*s.* per annum.

FOR THE CITY OF LONDON.

It is now understood that the Commissioners of Sewers for the City of London, after long and careful consideration, have decided to adopt Fryer's system of dealing with the refuse of Lett's Wharf, and under the able supervision of their engineer, Colonel Haywood, the works are being carried out by Manlove, Alliott, Fryer & Co., the principal structure being a 10-cell Destructor, of the most modern and approved construction, with several recent improvements. The furnace doors are made to balance on a wrought-iron shaft, and sufficiently large to allow of the largest clinkers being withdrawn entire, obviating the difficulty of breaking them up within the furnace in presence of the strong heat. The furnace doors are constructed of wrought iron, perforated, to admit air for more free combustion. At each side of the door-frame there are strong panelled castings, by which the frame, deadplate, and fire-bars are supported ; and the brickwork is protected against damage from the large and strong iron wheelbarrows employed to receive and remove clinkers and ash. Cast-iron boxes are built into the front to make room for the balance weights hung to the doors, and the ash-pits are fortified with iron curb-plates. The main flue is of even more enlarged area, to admit of larger deposits of dust, and 14-inch brick walls are carried across in order to break, control and partly baffle the powerful draught, so as to prevent the fine dust being carried up the chimney shaft. The height of the chimney shaft is 150 feet. It is 6 feet in diameter internally, and 16 feet externally at the base, with a lining of fire bricks 30 feet in height, supported by cross walls, and forming a cavity for the circulation of air to prevent the brickwork lining from being too much over-heated. The superfluous heat from the Destructor will be applied to generate steam in a boiler equal to working three mortar mills with pans 8 feet in diameter by means of a horizontal engine of 20 horse-power, having an 18-inch cylinder with a stroke of 3 feet. The steam power will be used also for hoisting the refuse to be consumed, and may further be used for generating electricity, and for cutting hay and other purposes of the depôt. The hoisting machinery consists of two distinct sets of gearing, each of which is calculated respectively to lift the number of loads of refuse required to be treated. In case of breakdown or repairs in progress, the spare gearing can be at once brought into use without interruption of the work. The hoists are driven by separate steam engines of six horse-power, which are fixed upon a high-level floor situated at one end of the Destructor, immediately underneath the gearing, and directly over the cart-way where the loads of refuse are brought to be lifted. Arrangements are provided by which the hoisting gear may be worked from the same floor, facilitating the control of the whole of the machinery by one attendant. Although the hoisting engines may be worked by steam from the boiler, already referred to as being heated by the superfluous heat from the Destructor, there is provided in addition a small vertical boiler, 10 feet high and 3 feet in diameter, to supply steam for the purpose from time to time on occasion, as at starting, or when it is necessary to burn street sweepings charged with too great an amount of moisture.

The refuse carts will be drawn under the hoist. They are so constructed that, without any other preparation whatever than connection with the lifting tackle, the body of the cart will be released and lifted from the frame and under carriage, leaving them with the horse on the ground. When sufficiently elevated to be placed on a horizontal line of rails laid overhead, the cart-load is hauled horizontally, by automatic gearing, until it arrives directly over the cell which is in readiness to receive the material. The rails consist of strong channel-iron, held by substantial hanger-brackets depending from the trussed wooden beams by which the roof of the main building is supported. The traversing gear is adapted to stop the progress of the load automatically, should the attendant not be present or neglect his duty.

The general buildings will be in correspondence with the handsome elevation of the stables, which have the appearance of a modern factory; while the chimney shaft will be massive and graceful, and will constitute an architectural feature visible from most parts of the Thames Embankment.

The total cost of the Destructor, with the engine, boiler, and mortar mills, is estimated to amount to about £12,000.

WATERING AND WATER SUPPLY.

To fill a cart with water and then to distribute that water over the surface of a carriage-way is a very easy and very simple operation. When the process has to be applied simultaneously, as near as may be, to a few hundred miles of streets, the operation becomes complicated and less easy.

During a spell of hot weather a practically unlimited supply of water is necessary for the proper maintenance and treatment of public thoroughfares, and where the water supply is in other hands than those of the local authority, difficulties and anomalies invariably present themselves.

In 1852, divers Acts of Parliament were passed, settling or professing to settle the improved and revised conditions upon which water should be supplied by the several then existing companies in the Metropolis for domestic and other purposes, and clauses defining the rates of charges at which water was to be supplied were introduced in those Acts.

Consequent upon the passing of the Metropolis Local Management Act in 1855, the management of the public thoroughfares in many parts of the Metropolis, passed from the hands of Commissioners, theretofore specially appointed for the performance of paving, cleansing, and other duties in certain districts of the Metropolis, into the hands of Vestries and District Boards of Works, whose jurisdiction was defined by the provisions of the Act—Metropolis Local Management, 1855.

Some difficulties arose in reducing to order, and in re-organizing the different and varying arrangements that had existed under those several Boards of Commissioners,* and it was found that diverse arrangements had been made for so small a matter as watering the streets.

Payment being made by the mile lineal in some cases,—by the square of 100 yards superficial in others,—and by the square yard—pure and simple—in yet other cases.

COST OF WATER.

The rates varied from 5*s.* per 100 square yards for one watering per diem, and 7*s.* 6*d.* per 100 square yards for two waterings per diem, for the "season" extending from Lady-day to Michaelmas-day.

The Companies gave notice during the first season to the newly-installed and inexperienced Vestries and District Boards of their intention to raise the charge from 5*s.* and 7*s.* 6*d.* to 8*s.* 4*d.* and 12*s.* 6*d.* per 100 square yards.

This increased charge was considered by the local authorities to be unwarranted, and they suggested to the Companies that the water should be supplied by meter, as required under the provisions of the several Water Acts.

This the Companies objected to do,—proposed to refer the question to the arbitration of a magistrate,—but after considerable negotiation consented to supply water for road-watering purposes at *not* an increased rate, but at the *reduced* rate of 4*s.* for once watering, and 6*s.* for twice watering per 100 square yards.

This was assented to by the local authorities as a reasonable reduction, for the time being, of the charges previously made. In 1860, the local authorities took further action, by again suggesting the application of the meter clauses of the Companies Acts, and after protracted negotiations the companies undertook to supply *by meter* at a certain fixed rate for every 1000 gallons, with the *addition* of 1½*d.* per 1000 gallons supplied *above* a certain defined height above Trinity high-water mark.

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* In the parish of St. Pancras alone there were no fewer than 17 Boards of Commissioners, exercising independent powers under separate Acts of Parliament. The Vestry exercised jurisdiction over short isolated lengths of carriage-way. There were 7½ miles of carriage-way under the jurisdiction of Turnpike Trustees, and there were four districts under no jurisdiction whatever, "No Man's Lands."

The rate then agreed upon was 1*s.* per 1000 gallons, with sliding scale of discount in the ratio of millions of gallons used ; but, in consequence of still further negotiation, this charge has been practically reduced to the uniform rate of 9*d.* per 1000 gallons, at which it now remains.

This charge represents a payment of 2*s.* 3*d.* for one watering, and 5*s.* 1½*d.* for two waterings, per diem, for the season, per square of 100 square yards, as contrasted with 5*s.* and 7*s.* 6*d.* paid in 1856, with the 8*s.* and 12*s.* 6*d.* proposed by the Companies in 1857, and with the 4*s.* and 6*s.* assented to as a compromise in that same year.

When payment for supply of water is made on calculation of the area watered, the agents of the Companies naturally see that none is wasted; they have, or assume to have, a control over the quantity of water distributed by the water-vans, and disputes and misunderstandings occur.

When the supply is by meter the necessity for such supervision and interference, as a matter of course, ceases ; a meter being fixed to each stand-post, by which the quantity of water used is gauged and measured for payment—at the cost of the consumer.

The cost of each meter is equal to two guineas per annum, and this adds in a material ratio to the cost of the supply of water.

The statement appended gives the quantity of water supplied from the several stand-posts in St. Pancras during the season 1883, watering being in that year commenced on 6th March and discontinued on 27th September.

It will be seen how various are the quantities drawn from the several stand-posts, although the site of each has been matter of careful consideration, and decided upon as the most advantageous available.

PARISH OF ST. PANCRAS.

DISTRICT SUPPLIED BY THE NEW RIVER COMPANY.

WATER FOR STREET WATERING, SEASON 1883.

Situation of Meter, and Standpost.	Consumption in Gallons.
Caroline Place .	269,000
Lansdowne Place .	255,000
Wakefield Street .	523,000
Gray's Inn Road .	661,000
Britannia Street .	385,000
Euston Road, by King's Cross .	1,056,000
Ditto, Duke's Road	142,000
Euston Square .	1,210,000
Burton Crescent .	825,000
Tavistock Place .	191,000
Endsleigh Street .	83,000
Gower Street . .	71,000
Hampstead Road (Ampthill Square)	630,000
Seymour Street .	354,000
Clarendon Square .	1,105,000
Aldenham Street .	314,000
Pancras Road. .	1,085,000
Bedford Street .	212,000
King Street . .	866,000
Camden Street .	1,034,000
James Street . .	462,000
Delancey Street .	438,000
Buck Street . .	559,000
Chalk Farm Road .	873,000
Victoria Road. .	900,000
College Gardens .	1,149,000
Hammond Street .	589,000
Prince of Wales' Road, by Kentish Town Road . . .	453,000
Grafton Road . .	941,000
Ascham Street .	686,000
Dale Road . .	424,000
Weedington Road .	1,086,000
Prince of Wales' Road (by Almshouses) . .	616,000
Carried forward .	20,447,000

Situation of Meter, and Standpost.	Consumption in Gallons.		Rate per 1000 Gallons.	£	s.	d.
Brought forward	20,447,000					
Malden Road	1,170,000					
Southampton Road	567,000					
Mansfield Road	320,000					
Carkers Lane (by Highgate Road)	360,000					
Dartmouth Park Road	679,000					
Chester Road	325,000					
West Hill, Highgate	60,000	Hydrants.				
Ditto	37,000					
Ditto	141,000					
Highgate Hill	267,000					
Chetwynd Road	260,000					
Leighton Road	379,000					
Fortess Road	260,000					
Torriano Avenue	861,000					
Crescent, Camden Road	147,000					
Rochester Square	892,000					
Cantelowes Road	375,000					
York Road	212,000					
	27,759,000		at 9*d.* =	1040	19	3
Rent of 51 water meters at 42*s.* each				107	2	0
				£1148	1	3

DISTRICT SUPPLIED BY THE WEST MIDDLESEX WATER WORKS COMPANY.

FOR WATER SUPPLIED FOR ROAD WATERING DURING THE SEASON 1883.

Position of Meter and Standpost.	Gallons used.
Munster Square	260,710
Fitzroy Street	1,062,460
Tottenham Court Road	1,291,630
Robert Street	1,121,720
Mornington Crescent	704,330
Cumberland Street, West	381,620
Carried forward	4,822,470

Position of Meter and Standpost.	Gallons used.	Price per 1000 Gallons.		£	s.	d.
Brought forward .	4,822,470					
Albany Street. .	776,460					
Gloucester Road .	898,050					
Berkeley Road .	809,390					
Total . . .	7,306,370	at 9*d.*	=	273	19	9
9 Meters at 42*s.* each	. .	. .	.	18	18	0
				£292	17	9

The total cost of water for the season was £1314 19*s.* The rent of meters was £126, or nearly 10 per cent. additional upon the cost of the water.

The three Hydrants on West Hill, Highgate, have been placed because the gradient of the hill is too steep for the use in safety of loaded water-vans or carts. To each a meter has to be fixed, the rent thereof bearing an excessive ratio to the cost of water—in the most extreme case two guineas being the rent of the meter, 27*s.* 9*d.* the cost of the water consumed.

Where water is used in other cases by the local authorities (not being for domestic purposes), the charge is also by meter.

For example, urinals erected for the public convenience have to be frequently washed out to ensure cleanliness, and a meter is supplied for each, the annual cost of meter being 10*s.* In many such cases the rent of the meter exceeds the cost of the water, as is shown in the table below ; but where the supply of water is constant, as in urinals of more recent and improved construction, the proportionate cost of the meter is considerably reduced because of the increased quantity of water consumed.

URINALS.

RETURN AS TO CONSUMPTION AND COST OF WATER.

	Consumption of Water.				Cost of Water.											
	1880	1881	1882	1883	1880			1881			1882			1883		
	Thousands.				£.	s.	d.	£.	s.	d.	£.	s.	d.	£.	s.	d.
Tottenham Court Road	98	108	223	668	2	9	0	2	14	0	5	11	9	16	14	0
..	..	..	..	..		..			..			..			..	
Ossulston Street . .	1	..	8	28			6		..			4	0		14	0
Gray's Inn Road . .	6	6	8	25		3	0		3	0		4	0		12	6
York Road	9	5	8	23		4	6		2	6		4	0		11	6
Goldington Crescent .	6	9	9	34		3	0		4	6		4	6		17	0
Pancras Road . . .	18	18	80	44		9	0		9	0	2	0	0	1	2	0
Mornington Crescent .	2	1	5	6		1	0			6		2	6		3	0
High Street	15	6	6	30		7	6		3	0		3	0		15	0
King's Road . . .	7	13	9	8		3	6		6	6		4	6		4	0
Camden Broadway . .	18	15	12	14		9	0		7	6		6	0		7	0
Kentish Town Road .	5	5	8	10		2	6		2	6		4	0		5	0
Chalk Farm Road . .	15	5	5	9		7	6		2	6		2	6		4	6
Seymour Row . . .	53	49	44	79	1	6	6	1	4	6	1	2	0	1	19	6
King's Cross Road . .	53	40	56	41	1	6	6	1	0	0	1	8	0	1	0	6
Oval Road	2	..	8	11		1	0		..			4	0		5	6
Brownlow Mews . .	..	6	11	19		..			3	0		5	6		9	6
Camden Gardens . .	..	..	..	316 18 mo		..			..			..		7	18 18 mo.	0
Angler's Lane . . .	..	..	..	373		..			..			..		9	6	6
Tottenham Court Road, by Chapel . . .	55	68	58	39	1	7	8	1	13	11	1	9	0		19	6
Percy Mews . . .	37	35	33	10		18	3		17	3		16	6		5	0
Albert Road . . .	9	10	5	..		4	5		5	2		2	6		..	
Cumberland Market .	7	7	7	..		3	3		3	3		3	6		..	

The first 18 Urinals on this list are supplied by the New River Company, who charge
on the list are supplied by the West Middlesex Water Works Company—the meters are

URINALS.

RETURN AS TO CONSUMPTION AND COST OF WATER.

Average Consumption for past 4 years.	Average Cost for past 4 yrs.	Number of Stalls.	Average Consumption per Stall per Annum.	Average Cost per Stall.	Remarks.
	£. s. d.		Thousands.	£. s. d.	
106 (3 years average)	2 13 0	4	27	13 6	Macfarlane's Urinal
554 (2 years average)	13 17 0	12	46	1 3 0	Jennings' Urinal, rent of meter 10s.
12 (3 years average)	6 0	6	2	1 0	
11	5 6	4	3	1 6	
11	5 6	3	3	1 6	
14	7 0	5	3	1 6	
40	1 0 0	5	8	4 0	
3	1 6	4	3	1 6	Rent of meter 10s.
14	7 0	12	5	2 6	
12	6 0	4	3	1 6	
15	7 6	4	4	2 0	
7	3 6	6	1	6	Rent of meter 10s.
8	4 0	6	1	6	
56	1 8 0	4	14	7 0	
47	1 3 6	6	8	4 0	
7 (3 years average)	3 6	4	2	1 0	
12 (3 years average)	6 0	3	4	2 0	
	say 5 10 0	6	35	17 6	Jennings' Urinal, rent of meter 10s.
	..	6	62	1 11 0	ditto
67	1 13 6	4	14	7 0	
28	14 0	2	14	7 0	
8 (3 years average)	4 0	4	2	1 0	
5 (3 years average)	2 6	4	1	6	

10s. each per annum for the water meter fixed in each Urinal. The four Urinals last the Vestry's, and are kept in repair at the cost of the Vestry.

DISTRIBUTION OF WATER.

The watering of public thoroughfares in large cities in the dry months of the year is a matter of detail requiring organization, but which usually fails to obtain general approval.

The practical difficulties are considerable, as the number of water-carts or vans required to meet the public requirements would have to be greatly increased if the wishes of the residents were always complied with. Each householder naturally wishes the carriageway in front of his own house watered at a time most convenient and agreeable to himself, and that in all probability would range from 9 o'clock in the morning till 7 o'clock in the evening.

But in thoroughfares of considerable traffic it is necessary to distribute water several times during the day. First it must be done early in the morning before the carriage-way is swept, and after the sweeping a second watering is necessary ; this would be about the time the traffic would commence, but shortly after all trace of watering would be effaced, unless the operation was again repeated.

In streets of lesser traffic the carts are sent round earlier in the day, in the middle of the day, and later in the evening, so as to work in with the exigencies of the heavier traffic.

But all these arrangements fail to command approval unless the residents themselves are practically familiar with, and give consideration to the difficulties of the operation· moral as well as physical. Gentlemen engaged in trade appreciate the value of plenty of water, and in many instances, secure profuse watering by illicit means of beer or other enticement. In one case a licensed victualler himself complained that the macadamized carriage-ways of a square in his immediate neighbourhood suffered from too much water, at the very time that some of the inhabitants of the square were complaining of dust, several calling attention to the profuse watering of the paved carriage-way in front of the particular complainant's premises, with the generous insinuation that a gratuitous supply of beer accounted for the extra supply of water.

Much of the efficiency of the water distribution depends on the regulations under which it is conducted. A little consideration will show the applicability of the principle that, in the morning the streets running north and south (except main thoroughfares) are to be watered before those running east and west, and the reverse of this in the afternoon. The sun being low in the morning, the streets running north and south would be wholly or partly in shadow for some hours, and would not dry up so rapidly as those streets running east and west, that are at the time exposed to the full force of the sun. The second watering must be arranged in the contrary way, as the full force of the sun at noon will be upon the roads north and south, while those east and west will be partly in shadow.

A full discharge of water should be cast upon the roads and over the entire surface each time of watering. Merely "laying the dust" is not sufficient, as in dry weather the effect is but very temporary. Experience proves that too much water is better than too little, although hasty and inconsiderate persons often complain of too much being used. It is easy for pedestrians to pick their way through mud, but they cannot escape from a cloud of dust. Besides the "clouds of dust" are seriously injurious to the goods in very many shops, and to the contents of private houses, but mud is not.

City of London.

The streets of the City of London are partly watered on the jet and hose system. In 1867 and 1872, experiments were made in washing the carriage-ways of Cheapside and the Poultry, when laid with granite pavement, and afterwards with asphalte pavement. The asphalte pavements of Old and New Broad Streets were likewise washed experimentally.

Hydrants were erected in Cheapside, at distances of 133 feet apart, and in Broad Street at 140 feet apart. Six men were employed at each washing of Cheapside in the first trial, and ten men in the second trial; for which two jets of water were used during the time of the first trial. The work of the ten men in the second trial was thus distributed:—four in playing the jets, two in moving the hose from place to place, and four with brooms in sweeping the surface of the asphalte, and keeping the channels free from straw and larger refuse. These men also used "squeegees" (india-rubber sweeps) to dry the surface of the asphalte; of the six men employed on the granite pavement, four played the jets and two moved the hose and plied the brooms.

WASHING CARRIAGE PAVEMENTS WITH JET AND HOSE.

RESULTS AND EXPERIMENTS IN THE CITY OF LONDON.

Particulars.	1867. Granite Pavement, Cheapside, etc.	1872. Asphalte Pavement.	
		Cheapside, etc.	Broad Street.
Length . . . feet	2,000	2,000	1,436
Area of pavement washed sq. yards	9,792	10,353	3,671
Time washing . . .	2 h. 19 m.	2 h. 4 m.	1 h. 3 m.
Area washed per hour sq. yards	4,220	5,000	3,500
Water consumed. gallons	19,500	19,726	9,786
Ditto, per sq. yard gallons	1·99	1·90	2·66
Cost of labour . . .	9*s.* 10¾*d.*	9*s.* 0*d.*	4*s.* 10¾*d.*
Cost of water at 6*d.* per 1000 gallons	9*s.* 9*d.*	9*s.* 10¼*d.*	4*s.* 9*d.*
Cost for labour and water, one day's washing . .	19*s.* 7¾*d.*	18*s.* 10¼*d.*	9*s.* 7¾*d.*
Cost for labour and water per sq. yard . . pence	·0241	·0218	·0315
Cost for labour and water per sq. yard per year pence	7·510	6·823	9·859
Add for supervision, preparing apparatus, wear and tear, etc., 20 per cent .	1·500	1·377	1·972
Total cost . . .	9·010	8·200	11·831

The granite pavement was more thoroughly cleansed by hose than in the ordinary way, by scavengers. The cost of washing asphalte was only 3 or 4 per cent. less than for granite.

Mr. Lovick in evidence before the General Board of Health, in 1850, stated that in surface cleansing by a jet and hose, the quantity of water consumed was at the rate of rather less than one gallon per square yard of surface of carriage-way working at "extremely low pressures." He mentions experiments made by Mr. Lee at Sheffield with "very high pressure," in which Mr. Lee effected the cleansing with a consumption of less than a third of a gallon per square yard. Mr. Lovick estimated that the footpaths could be cleansed with a consumpton of half a gallon of water per square yard. He adds that the daily cleansing could be effected at a cost of 3*d.* per house per week, exclusive of the cost for water; for which he allowed 28 square yards of carriage-way and 16 square yards of footway per house. At this rate, the first item of cost per square yard of surface would amount to 3½*d.* per square yard per year. For water, the cost at 6*d.* per 1000 gallons, would be 1½*d.* per square yard per year. The total cost would be 5*d.* per square yard per year.

Mr. Lovick at the same time estimated that the cost of cleansing by ordinary scavenging was nearly double the cost by jet and hose, whilst the jet had been shown to be much more efficacious in removing evaporating matter and filth.

It is found by experience in the City of London, that the most favourable period for using water is when the surfaces of wood pavements and asphalte pavements are in a moist and greasy condition. The mud can then be most readily removed from the surface by the water. In dry weather the system of jet and hose has also been employed, but when there has been a considerable fall of rain, it has not been found necessary. The washing is always done at the periods of the night when there is least traffic. The pavements of wood and of asphalte in the main thoroughfares, as well as those in the minor streets, are mainly those which are washed. The washing is performed on occasions throughout the year, and it has no doubt resulted in the streets being kept in a cleaner condition than before. The courts and alleys inhabited by the poorer classes are washed with jet and hose twice a week between the months of June and November. The quantity of water used for the washings of streets and alleys was, in 1882, upwards of 10 million gallons ; and in 1883 over 4½ millions.

Mr. Ellice Clark, a few years ago, recorded the results of observations in watering the streets and roads of Reading, where there were about 23 miles of macadam. Of these 17 miles were watered twice a day, for which purpose 11 watering carts and barrels and 4 hand-watering machines were employed. One cart waters a length of 5962 lineal yards, having an area of 23,849 square yards, twice a day, at a cost of 8*s.* for horse, cart, and man, and 1*s.* 5*d.* for maintenance of cart and harness, and shoeing ; total 9*s.* 5*d.* per day. With one hand machine 23,740 square yards are watered twice daily, at a cost of 2*s.* 10*d.* each for two men, and 7*d.* for maintenance ; making a total daily cost of 6*s.* 3*d.*

	Area watered twice daily.		Cost per day.	Water delivered per sq. yard.
One water cart	23,849	sq. yards	9*s.* 5*d.*	0·51 gallons.
One hand machine	23,740	„	6*s.* 3*d.*	1·30 „

IMPROVED DISTRIBUTION.

In 1872 a new water-van was introduced in the Metropolis by Messrs. E. H. Bayley and Company, of Newington Causeway, constructed by the firm on plans suggested by and arranged with the Authorities of St. Pancras. Several novelties were introduced, the principal improvements being increased capacity in the tank (450 gallons in place of the 220 gallons of the old water-cart), the mounting of the tank on four wheels instead of two, and the exact balancing of the tank, so that the draught of the van should be less trying to the horse, the animal being at the same time relieved from the heavy weight on the cart shafts and the straining action on the shoulder produced by the swaying of the water in the two-wheeled cart. It was found, as calculated, that 48 vans, in less time, did work equal in area to that previously done by 72 carts, at a reduced outlay for horse hire of about £30 for each van per annum.

The success of "Bayley's Hydrostatic Van" was pronounced, and it was rapidly adopted in almost all the towns in the Kingdom, in Europe, South America, and many of the Colonies, as many as nearly 2000 being called for in the ten years.

Success begets imitation, and Bayley's van has of late years been widely imitated by many van builders, so that there is no difficulty in obtaining it or some of the imitations; but Bayley's van has not been materially improved upon. Variations of detail have been introduced by the imitators, but such of those as are really new are not good, and those that are good are not really new.

The following statement gives a comparison of the day's work (6 A.M. to 5.30 P.M.) of a Bayley's Hydrostatic van, and of an ordinary water-cart superseded by the van.

	Bayley's van.		Water cart.	
Capacity of tank in gallons . .	450		220	
	Hours.	Minutes.	Hours.	Minutes.
Average aggregate time of filling .	1	58	1	56
Travelling from standpost to work and back, aggregate . .	3	26	4	49
Aggregate time of spreading .	4	21	3	0
Day from 6.0 A.M. to 5.30 P.M.—Rest: breakfast, ½ hour; dinner, 1 hour.				

The aggregate time of filling depends upon the pressure in the main to which the standpost is attached. The time occupied in filling a van varies from two to seven minutes. A cart proportionately less, but the cart of course has to make a larger number of journeys to cover the equal area.

SNOW.

Removal of Snow.

No practical provision is made by systematically organized arrangements previously decided upon in the large cities of Great Britain for the removal of snow, although as concerns the Metropolis very elaborate and stringent provisions were enacted by Michael Angelo Taylor's Act, 57 Geo. 3, cap. 29 [1817], and repeated in other statutes, as may be judged by the following clause.

Footways to be swept daily during frost and snow.*

63. "And be it further enacted, that every occupier of any house, tenement, warehouse, shop, shed, coach-house, stable, chapel, meeting house, or other public or private building in any street or public place in any parochial or other district within the jurisdiction of this Act, during the continuance of frost, or after or during the fall of snow, from time to time, and at all times hereafter, shall once in every day before the hour of ten of the clock in the forenoon of each day, except Sunday, sweep and cleanse, or cause to be swept and cleansed, the footway all along the front side or back walls of their respective houses, tenements, warehouses, shops, sheds, coach-houses, stables, chapels, meeting houses, or other public or private building; and that every occupier who shall neglect so to do shall for every such offence forfeit and pay any sum not exceeding the sum of 10*s*., to be levied and recovered and applied in such and the same manner in which other penalties are by this Act hereinafter directed to be recovered and applied; and also that the owner or owners of any house or other tenements within

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* See also 2 & 3 Vict. c. 47, s. 60, for further improving the police in and near the Metropolis.

the jurisdiction of this Act, which may be let, furnished, or in divided apartments, shall be deemed and taken, for the purpose of this provision, to be the occupier or occupiers of every such house or other tenement respectively."

That reads very well, is stringent enough, and sounds as if it ought to be effectual, but in experience it is found to be absolutely inoperative for all practical purposes.

At times, for periods of several years, the Metropolis is not visited with a heavy fall of snow, and when such fall does occur, the constant variations of temperature are such that the visitation seldom leads to great inconvenience.

FROM FOOTWAYS.

The sundry provisions made by Acts of Parliament require every householder to remove snow from the front of his residence before a fixed hour in the morning, but in very few instances do the householders trouble themselves to comply with these requirements.

The inhabitant of one house may very conscientiously send out a man to cleanse the footway, whilst his next door neighbour religiously refrains from doing anything of the sort. A large percentage of householders do not think it worth while to give any attention at all to the matter, until incidentally a labourer with broom and shovel comes along and offers to "clean your door-step."

By such time the snow has become trodden down and hardened, and consequently more dangerous to pedestrians and more difficult of removal.

In this, as in many other matters, there are duties imposed alike upon the police and also upon the Local Authorities. Notices to remove snow are in no instance served upon the householders before the fall, and such a service after the snowfall is necessarily too late to ensure attention to the desired purpose.

In the event of householders being careless or obstinate and neglecting to clean the footway in front of their houses, the police may take out summonses against a few or against a large number. If only a few are summoned, they complain when before the magistrate of being selected, and urge that all should be served alike. If a large number be summoned, the magistrate takes objection to the time of the court being wasted, remarking perhaps that one summons would have established a case and a precedent. Again, some ten days elapse between the issue of the summons and the hearing before the magistrate, during which time a thaw has set in and the snow has disappeared. Probably the first question asked by the magistrate is, "Is the snow there now?" and the answer being in the negative, the magistrate curtly says, "summons dismissed," the householder is pleased to escape, on the next snowfall neglects his duty again, and the police authorities are disheartened at their failure and are not zealous in future.*

Now if the Legislature be in earnest in requiring every householder to cleanse the footway in front of his house when there is a fall of snow, or if the community itself be in earnest in the matter, the procedure is clearly defective, to say the least of it.

A much more satisfactory system would be somewhat as follows.

At eight o'clock in the morning—if that be the hour fixed—police constables or other duly appointed authorities should pass along the streets and record the number of every house where the footway is not cleansed from snow. A report of the facts, with a list of these houses, should be laid before a magistrate on that day, and a fine absolutely and necessarily imposed upon every person included in that list. This would have the effect in a very short time of inducing the residents to make it expedient to arrange with labourers (who might easily be dealt with at such seasons, when employment is scarce,) to do the necessary work before the specified time at a very trifling cost.

Even this would require a certain amount of organization. The arrangement would have to be made in anticipation

* This is narrative of fact.

of a fall of snow, and the necessary number of men would have to be provisionally engaged by a foreman or ganger, who would make himself responsible to the residents of the particular street.

In the absence of such an arrangement as this, and if considered desirable, as in many instances it would be, that the Local Authority should undertake the duty at present cast upon the householder, prevenient organization would meet the difficulty. Gangs would be—provisionally—formed for certain streets, and unemployed labour would be in anticipation drafted into such gangs for employment in event of snowy weather.

FROM CARRIAGE-WAYS.

In great cities the absolute removal of snow from the whole area of the public ways is extremely difficult.

In the immediate vicinity of rivers a certain quantity of snow can generally be discharged and carried away by the running stream at once from the town; but where town extends miles from the banks of the river the stream ceases to be an available medium of removal.

Should the residents clear their footways, the accumulation of snow becomes great, and from time to time greater, in the roadway, because the local authority alone is required to keep the carriage-way free.

Even in thoroughfares where the traffic is great and snow ploughs are used, the snow is not always removed effectively, the plough simply clearing the middle.

The centre of the carriage way alone is available for traffic, which is rendered possible and facilitated only by the Local Authority maintaining the same by the free use of gravel or salt.

Salt dissolves the snow, but by many medical men it is considered an extremely injurious operation.

The use of gravel is a partial remedy. It enables the traffic to be conducted along the carriage-ways by the constant and repeated application, and this may be facilitated by the use of numerous sanding machines.

A succession of snowfalls of course increases the difficulty of applying palliative remedies, and at times it is found that the traffic must be stopped unless the snow is actually removed and as quickly as possible.

The great difficulty in large towns is to find spaces to which to cart the snow, and the larger the town the greater the difficulty, generally because of the scarcity at such times of vacant space.

The snow could be deposited in the parks, but the verdure would suffer, and in paved open spaces an accumulation is objectionable, for the reason that it would remain there for weeks after the thaw had set in.

In such a great city as the Metropolis, if prevenient arrangements had been organized, it would be feasible to remove the snow in its earliest stages into the deeper sewers, where it would be rapidly dissolved by reason of the higher temperature; but the authorities having jurisdiction over these sewers might object to the intrusion of an authority having jurisdiction only over the surface. In fact, cases have occurred where the sewer authority has objected to the sweeping of melted snow down the gullies having connection with the sewers below, although the snow must necessarily have become dissolved long before it could have reached the deeper sewers. The mud from the surface of the roads which might have been swept into the gullies with the snow would simply represent the detritus, that would have been immediately and necessarily swept into the sewers if the snow had descended in the form of rain.

SNOW STORMS.

There have been of late years—notably, 1867, 1871, 1875, 1876 and 1881—a few heavy snowstorms in the Metropolis, when special means were necessarily adopted for dealing with and removing the snow.

CARTING SNOW.

One of these occurred early in the morning of Wednesday, the 2nd of January, 1867. In the parish of St. Pancras (mileage of carriage-ways about 80 miles), the first step taken for dealing with the snow, was to clear the gullies and channels of the main thoroughfares. Then the snow was cleared away for a width of about ten feet from the kerbs, where it was loose and easy of removal. The work was continuously carried on from Wednesday morning until Saturday night ; 300 men with 120 carts were employed in the operations, and over 7000 loads of snow were removed. A thaw set in on Sunday morning. Nearly 300 men were employed during that day in keeping the gullies and channels clear, not only in the main thoroughfares, but also in the side streets. The efficacy of the operations that were undertaken was demonstrated by the fact that, rapid and sudden as the thaw had been, there was no case of flooding in any road in the parish. Shoots were improvised in the open squares and on the open space now marked by the Cobden statue, where a huge mountain of snow was accumulated. Nevertheless, whilst there are 80 miles of road in the parish, the work of clearing away 7000 loads of snow, extended over only 10 miles of carriage-ways. These figures give 700 loads of snow removed in partially clearing one mile of way ; and they demonstrate the difficulty and arduous nature of the work to be done in any endeavour to remove a "snowfall." As to the supply of labour, all who applied were engaged, though there was no great readiness to fall to work. A party of eight "got-no-work-to-do" able-bodied men were singing in the carriage-way past the offices. They were hailed, and shovels offered to them. Wages, 3*s.* a day, to lift light snow into carts. They declined the offer of work, and went on their way singing—it should have been, "we-want-no-work-to-do."

GRAVELLING THE CARRIAGE-WAY.

On the occasion of the snowstorm of 1871, a different course was adopted in St. Pancras for dealing with the carriage-ways during and after the storm. The gullies and channels were first cleared as before, but the snow was spread over the crown of the roadway. The number of hands employed amounted to 390.

Little more snow fell; but for 12 days, during the continuance of the frost, the main thoroughfares were continuously dressed with gravel, burnt ballast, granite sand, and screened Thames ballast, and the traffic was maintained with comparative ease. About 1500 cubic yards of material were distributed during the twelve days, at an outlay of £375. When the thaw set in, the "sweeping gangs" were further employed in clearing the roadway and facilitating the escape of the water to the channels, and in sweeping the main thoroughfares. The extra labour cost £250.

SALTING THE CARRIAGE-WAY.

After the snowstorm of the 2nd December, 1875, followed by frost, terminated by a thaw on the 10th, the system of melting by the use of salt was adopted in St. Pancras. Coarse agricultural salt was freely applied in the middle portions of the carriage-ways; and the liquid slush was assisted by brooms and scrapers through grips cut in the accumulated snow at the sides into the channels and thence to the gullies.

Another fall of snow took place on the 12th of January, 1876, succeeded by a thaw which set in on the 17th of the same month. The efficacy of the salting process was again tested; and it is convenient to form some comparison between the results of the salting treatment on the two occasions of snowfall in December, 1875, and January, 1876. On the first occasion eight roads were partly salted by the Tramway Company, fourteen roads partly by the Omnibus

Company; and 106 roads and streets for the whole width by the Vestry. Of the 22 streets partly salted by the tramway and omnibus companies only the middle of the carriage-ways were treated by the companies, the sides being salted by the Vestry. On the occasion of the fall in January 1876 the carriage-ways which were salted were somewhat more numerous. The quantities and costs were as follows:—

	Dec. 1875.	Jan. 1876.
Salt, chiefly coarse salt, consumed .	42 tons.	36 tons.
Cost of salt used	£82	£75
Snow carted away	1769 loads.	465 loads.
Cost of carting away snow . .	£331	£87
Cost of extra hands employed . .	£195	£45

EFFECT OF SALT.

The experience gained showed that the use of salt is an efficient mode of dealing with the snow; that, used in liberal quantities, it rapidly melts the snow, and that the greater the traffic the more speedily the snow is melted; but that it is absolutely necessary that the mixture of salt and snow should be swept away as rapidly as possible after it assumes a liquescent condition. Weak macadam roads are seriously affected by the mixture, for the salt appears to penetrate and disintegrate the softer material under the shallow coating of granite or hard surface material. The grouting of paved roadways would seem also to be injuriously affected by it.

The report of the Medical Officer of Health to the Vestry of St. Pancras, made in January 1876, throws much light on the risks incurred to health by the use of salt, the absorption of brine into boots and shoes, and the permanent state of cold dampness which ensues. The following is the text of the report:—

"I am of opinion that the salting of frozen roads, for the purpose of thawing them, may be attended with consequences injurious to the health of the public.

"When ice or snow is melted by mixing it with salt, the temperature of both substances is greatly lowered, and the resulting liquid brine has a temperature about 30 degrees below the temperature of the substances before admixture. Any one stepping into such cold brine might receive a very severe chill in the feet, and serious consequences might ensue.

"After the lapse of some time the brine attains the temperature of the ground upon which it rests, but although the brine remains liquid it is not warmer than the neighbouring ice and snow, and, until a general thaw sets in, the brine remains icy cold. To step into such brine might cause a dangerous chill of the feet.

"There is a further and perhaps more serious danger from the following causes: boots saturated with brine are dried with the greatest difficulty, and only by the aid of a moderately warm atmosphere and a free current of air. When dried they again readily absorb moisture from the atmosphere, and become again moist. In fact, boots soaked in brine will not dry upon the feet in very cold weather. If the public, during a frost, are compelled to step upon briny, slushy roads, they will have to go about in damp boots, and this could not fail to be prejudicial to health.

"I believe that in one way only could salt be used with safety for thawing ice-bound roads in large towns. This would be to thaw the roads by means of salt, and immediately afterwards to remove the liquid slush, and coat the roads with sufficient sand to render them dry again."

SALT AND SEWERS.

In dealing with the snowstorm of the 18th of January, 1881, which lasted eighteen hours consecutively, in St. Pancras salt was at once freely applied along all the main thoroughfares by the tramway and omnibus companies, and by the Vestry in the manner described in dealing with the storm of December, 1875. Sixty-five tons of salt were disposed of. The central portions of the main thoroughfares were, before the lapse of many hours, made passable, and extra hands were engaged to clear channels, and remove the snow from intersections of important thoroughfares. No attempt was made to remove the *bulk* of the snow by cartage, although 2000 loads were actually removed. Nearly 650 men were employed on the same work. Nearly 500 loads of snow were discharged into the district sewers. The warm temperature below quickly disposed of the snow ; but there was no chance of flooding the sewers, as the delivery of the snow into the sewers was but comparatively gradual. The steps taken to clear the fall of snow may be summarised as follows :—

1st. The employment of an unlimited number of labourers to drag the snow from the middle of the roads to the breasts. About 500 voluntered, and were taken on at 3*s.* 6*d.* per day, with a proportionate increase in the number of supervisors.

2nd. Reduction of the snow by salting profusely those streets as the clearance took place.

3rd. Clearance of channels with gaps cut in the snow accumulations, and profuse salting so as to facilitate drainage and the rapid sweeping of slush to gullies.

4th. Cartage of snow, firstly, from all important intersections, subsequently from the main roads.

5th. Deposit of white snow in the district sewers by means of the side-entrance galleries, with a sufficient number of men underneath to keep it below the level of the drain-mouths, and the use of pure carbolic acid to ensure more rapid melting.

In the City of London, visited by the same snowstorm of January 18, 1881, it was estimated by Colonel Haywood that the fall of snow averaged 6 inches in depth, making about 500,000 cubic yards on the entire area of the city. It was estimated that 133,000 yards were on the public ways, of which 70,000 were on the main lines of thoroughfare. Attempts were made to melt the snow, before the fall had ceased, by sprinkling it with rock-salt, but they were not successful. The quantity of snow actually carted away was approximately as follows:—

	Cubic yards.
3,615 days of extra single-horse cartage . .	54,225
111 days of two-horse carts	2,220
7,000 loads removed by Commissioners' carts .	14,000
Total removed	70,445

The greater portion of the snow was carted to London Bridge and Blackfriars Bridge, and there shot on to the footpaths, whence it was shovelled over the parapets. Large quantities were deposited upon land at Golden Lane, 2 acres in extent, that happened to be available, and on open spaces elsewhere. The work of removing the snow lasted twelve days, till the 29th January. The number of extra men employed in the work was increased from 233 on the 18th to 1368 on the 24th, and reduced to 137 on the 29th, the last day of clearing. These were in addition to 350 men and boys in the regular service of the Commission. The total cost of the work, exclusive of ordinary daily expenditure for the cleansing of the public ways, amounted to £4254. During the same period, 1,812 loads of ordinary dust and refuse were removed from the streets.

SNOW-CLEARING IN MILAN.

In Milan, the snow-carts are emptied into the navigable canals and numerous watercourses by which the city is intersected; and latterly also into the new sewers in the central portion of the city, which are promptly flushed whenever it snows. During the winter of 1879–80 the cost of clearing the 1,656,200 square yards, total area of squares, streets, and lanes within the city walls, averaged £200 per inch depth of snow fallen, and for the 502,800 square yards outside the walls the average cost was £62 per inch depth, equivalent in each case to about 1·05*d.* per cubic yard. Ordinarily the clearing of the more frequented streets is completed within eight or ten hours after it has stopped snowing; and of the rest within twenty-four hours, not reckoning night.

The organization of the arrangements by which this work is accomplished with such remarkable despatch and efficiency, is the work of Signor Annibale Gafforini. The city is parcelled out into small districts, numbering 112 for last winter, of varying extent, according to the importance of the work in each. An average rate of pay per inch depth of snow fallen is settled for the whole area of each separate district, according to its extent and the particular conditions affecting the several districts and squares comprised within it. Each district is allotted to a contractor, who usually associates with himself six to ten partners, besides the labourers whom he employs. He has to find carts, horses, and carters; the necessary implements—spades, shovels, brooms, scrapers, mattocks, barrows, &c.—are furnished by the city, under suitable stipulations for ensuring proper care in their use. A copy is given of the complete form of contract now employed, comprising upwards of thirty clauses. The contracts are made annually, and the same persons almost always apply for them again year after year. The contractors come principally from the trades that are interrupted by winter—paviours, bricklayers, and masons, and gravel quarrymen. For the direction and supervision of the work the whole city is divided into four sections, over each of which is appointed an engineer with an assistant, who are aided in the general arrangements by police surveillance.

Payment is made only for work effectually done. In each snowstorm the depth of snow falling, which is the basis of pay, is ascertained by means of a number of stone posts, fixed in suitable open spaces, clear of shelter from buildings, and each capped with a flat horizontal slab of stone. As soon as it stops snowing, or two or three times during a storm of several hours, the depth of snow, caught on the slabs, is measured by the engineer in the presence of two of the contractors in his section.

The number of men ordinarily engaged in snow clearing on a winter's day is not less than 2000 and has sometimes risen to 3000. The stock of implements found by the city, representing a capital of about £1600, is housed in two stores in opposite quarters of the city. In the winter of 1874–75 the total fall of snow amounted to 40¾ inches, and the whole expenditure for clearing it within the city walls exceeded £8400; while in 1877–78 the fall was only 5¼ inches, involving an expenditure of less than £1040 for a slightly larger area.

SNOW-CLEARING IN TURIN.

Turin and its suburbs are divided into three districts, of which two are urban, comprising all the paved roads, and one district is surburban, comprising all communal roads. Each district is subdivided into sections varying in number from five to eight. The work is done by petty contractors, who find labour, horses and carts, and is paid for at a price per centimetre of snow fallen. The city provides tools. The street-sweepers are also employed at the intersections of main streets and other important points, and to sprinkle sawdust, &c. on the roads.

The snow is first thrown up into heaps and then thrown into the sewers, rivers and canals, or stacked in special places. The sewers are flushed from a canal in the upper part of the city.

Several mechanical methods of melting the snow have been investigated with the following results. Garneri's tube calorifer consists of a galvanized iron pipe with a fire at one end, and a fan for drawing hot air through it at the other. The snow is heaped round the tube. The cost amounted to 2⅓*d.* per cubic yard (without reckoning the cost of the apparatus) as against 1*d.* per cubic yard for clearing away in the usual manner. The pyrohydro melting plough was a machine proposed by Garneri for melting the snow *in sitû*, but did not seem worth trying. Nawckins and Mullaly's (New York) snow melter consists of a boiler from which a mixture of steam with the gaseous products of combustion issues in one or more jets upon the snow. The cost for fuel alone would be ¾*d.* per cubic yard of snow melted, to which must be added interest and sinking fund for machine, costing £1280. Bouvet's system resembles the tube calorifer, but the tube is pierced with small holes from which steam issues. Melting by salt.—It has been found in Paris that 0·36lb. of salt is required to melt a frozen stratum 1 yard square and 1½ to 2 inches thick. The price of salt in Turin being 2*s.* 4*d.* per lb., the cost would amount to 16*d.* per cubic yard. Wells as receptacles for snow.—It not being thought advisable to try any of the above systems, it was proposed that a well should be dug to receive the snow from one contract. The subsoil of the city is gravel, through which a large body of water passes. A well 16 feet 6 inches in diameter, 42 feet 6 inches deep, amply sufficed in 1880-81 to receive the snow from an area of 13,150 square yards. This system is rapid and economical where the cost of cartage exceeds ¾*d.* per cubic yard.

The area from which the snow was removed in 1880–81 was 2,800,000 square yards; the total depth of snow was 1·41 foot. There were 121 contractors. The number of men sometimes amounts to 4000 (besides the regular sweepers), and 500 carts. On January 19, 1881, 3684 men, and 475 one-horse carts were employed to clear away a depth of 0·46 foot of snow. The average cost for clearing and carting a cubic yard is 0·93*d.* in districts 1 and 2. In district 3, where it is only heaped up, it is 0·4*d.* In addition to these amounts paid to the contractors there is the cost of providing and maintaining tools, and the charge for canals, &c.; these items, with superintendence, add from 20 to 25 per cent. to the cost. The total cost per inch depth of snow is £274.

The tramway companies have to bear their share of the cost, and pay for clearing a width of 9 feet 10 inches for single, and 19 feet 8 inches for double lines. For a length of 17½ miles of tramway, the cost is £12 11*s.* per inch depth of snow.

The question of letting the work to one or two large contractors has been considered by the authorities, but the present arrangement is thought to be the best. In the event of dispute with a large contractor, the snow would be left lying in the street, while the men now employed can be dismissed at a moment's notice and readily replaced, and they are satisfied with a lower rate of pay than a contractor would demand, who provided his own tools, and was required to have large gangs of men always available, with the possibility of having no work for them throughout the winter. The superintending staff consists of twenty engineers and assistants, who take great interest in the work, which involves much responsibility in cases of emergency. In the busiest parts of the city, the snow is heaped up by 9 A.M. when the depth does not exceed 6 inches, and is cleared away within twenty-four hours. In all the inhabited parts, the heaping up is done in one day, and the removal in two days more.

SCAVENGERING OF PARIS.

THE cleansing of the public thoroughfares in Paris, formerly undertaken by the Prefect of Police, is now a function of the Prefect of the Seine. The staff consists of two engineers, one for each group of arrondissements, one group being subdivided into three sections, each under the charge of an executive engineer, and the other into five sections, similarly supervised. These sectional engineers have under them fifty-one superintendents, and sixty-one overseers, whose employment imposes upon the municipal budget an annual cost of 260,000 francs. The scavenging plant is kept in a central depôt, where materials of every description are stored and classified for ordinary and extraordinary service when snow and ice render additional assistants necessary.

The roads of Paris extended in 1877 over a length of 558 miles, and they covered an area equal to 3,523 acres, more than 18 per cent. of the total area of Paris within the fortifications.

	Square yards.	Square yards.
Paved roads	6,349,527	
Macadamized roads. . .	1,972,582	
Asphalte roads . . .	296,127	
		8,618,236
Unmetalled roads (natural surface) . .		242,782
(53 per cent.) Total area of the roads . .		8,861,018
(47 „) Footpaths and blind alleys .		6,691,636
Total of all classes.		15,552,654

The depôts contain supplies of chloride of lime, sulphate of zinc, sulphate of iron, and carbolic acid, as disinfectants; and hydrochloric acid, nitro-benzide (*acide de mirbane*) as cleansing agents. The chloride of lime, of a strength of 100° to 105°, is successfully employed for the disinfecting of places tainted with urine or fæcal matter, also for the cleansing of gutters carrying sewage matters. Sulphate of iron and sulphate of zinc are both used under the same conditions. Sulphate of iron possesses the disadvantage of rusting objects to which it is applied. Sulphate of zinc is stronger in its action, but costs a little more. It produces no smell, nor does it leave any trace. It is much employed in summer in washing and watering the basements of the *halles centrales*, used for fish, poultry, and offal. At a strength of $\frac{1}{8}$th, and mixed with 3 per cent. of sulphate of copper, sulphate of zinc makes a good disinfecting liquor, which preserves its qualities a long time, and is of great use in private houses. Carbolic acid is not, strictly speaking, a disinfectant; it does not act like chloride on putrid matter, but arrests and prevents fermentation, doubtless by destroying the spores. It is, therefore, always employed when it is desired to destroy the germs of putrid fermentation. It is used at a strength of about $\frac{1}{40}$th, say a gallon of the acid to 40 gallons of water. At a strength of $\frac{1}{100}$th and $\frac{1}{200}$th it gives good results for watering once or twice a week in summer those parts of the *halles centrales* liable to infection. It is even used as low as $\frac{1}{1000}$th for watering streets and gutters. Hydrochloric acid is applied to urinals and slaughter-houses. In places much incrusted with tartar, it is used at a strength of $\frac{1}{6}$th. Lowered to $\frac{1}{10}$th, it cleans smooth walls and flags efficiently. In ordinary rinsings a strength of $\frac{1}{15}$th suffices. It leaves a disagreeable odour behind, which however is quickly dissipated. Mirbanic acid (nitro-benzide) is more energetic than the foregoing, but it produces a disagreeable smell of bitter almonds, and leaves a white film which has to be washed off. It is used at the same strengths as hydrochloric acid. The annual cost for plant and disinfecting materials of all descriptions is £8800.

The engineers of the city of Paris are also charged with the sweeping of the roads, which is performed daily, between 3 and 6 A.M. in the summer, and between 4 and 7 in the winter. The carts for removing the public and private refuse work from 6 to 8 A.M. in the summer, and from 7 to 9 in the winter. The filling of each cart is attended to by the driver, aided by two shovellers, the latter having to provide during the rest of the day supplemental sweepings wherever required, to rinse the gutters twice a day, and to clean and disinfect urinals, &c. These matters are ordinarily finished by 4 o'clock in the afternoon, except in unfavourable weather. The engineers have at their disposal a staff of—

	Fr.	C.		Fr.	C.	
2200 men, at from .	2	50	to	4	0	per day.
950 women, at from .	0	20	to	0	25	per hour.
30 children (boys), at .				0	20	,,

In addition there are 190 mechanical sweepers, and as each machine represents the effective work of 10 men, the total scavenging staff may be considered as composed of nearly 5000 labourers.

The mechanical sweepers, which after numerous trials and much hesitation, have been introduced into Paris, are the English machine, improved by M. Sohy, and the machine of M. Blot, the former being preferred. The mechanism of both is simple, works with regularity and occupies little space; it consists of a framework upon two wheels, with a seat for the driver. At the back is placed the sweeping apparatus, composed of an inclined circular bass broom, actuated by gearing driven from one of the wheels of the carriage. By means of a clutch the driver can from his seat easily put the broom in or out of gear. The machine is employed in all weathers, and works as well on paved roads as upon macadam or asphalt. Each machine weighs rather over 14 cwt. and can be drawn by one horse. It sweeps about 6578 square yards per hour. The cost of a machine is £40, and its annual maintenance, exclusive of renewals of the brush, £8. The cost of a new brush is about £2 16*s.* 0*d.*, which will work for from one hundred and sixty to two hundred and eighty hours.

The Paris mud no longer possesses the manurial strength of former times, and in consequence the receipts derived by the municipality from this source have greatly diminished. It is at present disposed of by public tender to responsible contractors for terms of about four years. For its removal there are daily employed 520 carts and 980 horses. The average bulk removed per day is about 2223 cubic yards.

SNOW.

When a fall of snow occurs, attention is first directed to clearing the footpaths and crossings, so as to insure uninterrupted circulation of foot passengers. The town scavengers sand the roads wherever it is necessary for the carriage traffic. At the same time numerous auxiliaries are organized to remove the snow from the principal thoroughfares, in the order of their relative importance. For removing the snow the General Omnibus Company are bound by their concession to furnish fifty waggons; and carts are specially arranged for with the providers of sand and gravel at the beginning of winter, the contractors for maintaining the public roads being also bound to hold their carts at the disposition of the sectional engineers. In certain cases the half-melted snow is swept into the sewers, especially those carrying warm water. Melting by steam has been tried, when a continuous jet was introduced into a mass of banked snow; but it melted very slowly at first, and the melting ceased after the cavity had increased to a certain size. Two descriptions of snow-plough are kept in store, one for manual the other for horse-power; but they have never been used, as the coating of snow seldom attains sufficient thickness, and as it is too quickly compressed and hardened by the traffic. As a rule the sum allowed in the budget, about £7000, suffices for the extra labour incurred; but occasionally severe winters cause this to be greatly exceeded, as in 1875–76, when the increase amounted to £8000.

WATERING.

Both hose and carts are used for watering the thoroughfares, the former for the boulevards, the avenues, and a certain number of first-class streets. The watering plant belongs to the municipality. Three descriptions of cart are in use ; two heavy wooden ones are now being superseded by the third, Sohy's cart, made of sheet iron. The carts contain 220, 242, and 286 gallons respectively, and will water from 2400 to 3350 square yards. The watering by hose is attended to by the ordinary street cleaners, who can easily water 24,000 square yards in thirty-five minutes, deducting the time necessary to connect the apparatus with the mains. There are three hundred and twenty-two water carts, which on the average disperse 1,311,200 gallons of water over a surface of 7,139,163 square yards. A surface of 2,783,092 square yards is watered by hose, and this system is being greatly developed on account of its convenience and cheapness. The annual cost of watering is £18,000.

The cost per year for maintenance and scavenging, exclusive of general charges, was for the first, second and third roads already noted, as follows :—

	Maintenance per Square Yard.	Cleansing per Square Yard.	Total per Square Yard.
Stone pavement . .	4·50*d.*	3·37*d.*	7·87*d.*
Macadam . . .	9·25	7·31	17·26
Asphalte . . .	10·20	4·17	14·37

Here is shown that asphalte costs nearly as much as macadam for maintainance and cleansing ; and if the interest on the excess of original cost for asphalte above that for macadam be added, the annual charge for asphalte will be greater than that for macadam.

The amount of special charges for urinals, watering, removal of snow and ice, &c., is at the rate of $\frac{7}{8}$*d.* per square yard.

SCAVENGERING OF LILLE.

The town of Lille is one in which the scavenging is most thoroughly done. The road scrapings are greatly prized as fertilizers by agriculturists in the neighbourhood. It costs the local authority 1*s.* 6*d.* per cubic yard to collect the refuse and to carry it to the depôt; and it is sold to the farmers for 1*s.* 2½*d.* per cubic yard, securing a ready sale. The cost of carriage by rail is 1*s.* 5*d.* per cubic yard, for a distance of six miles, and 2*s.* 3*d* for thirty-six miles. According to the results of analyses of old and recent samples of road scrapings, it is found that the theoretical values are, in the former case, 3*s.* 9½*d.* per cubic yard, and in the latter, 3*s.* 8½*d.* The mud deposit in sewers and drains contain from eighty to ninety per cent. of water, and is most foul and fœtid. After partially drying it till the water is reduced to 50 per cent., the residue contains nitrogen, 0·675; phosphoric acid, 0·81; potash, 0·18 per cent.; and the amounts are not greatly decreased when the deposit has been taken to a depôt, and stored for a time until it becomes partially air-dried.

SCAVENGERING OF BOSTON, U.S.

The scavenging of Boston devolves upon a committee of five members of the City Council, chosen annually. This committee, in January, makes an estimate of the appropriation required for scavenging during the year, and controls its expenditure; all work and the employment of all labour being in its hands. It is provided, however, by City Ordinance that scavenging shall be done to the satisfaction of the City Board of Health, and that the superintendent in actual charge of the work shall be appointed annually by the said Board, and approved by the Mayor. The Board of Health referred to consists of three members, appointed by the Mayor for three years, and approved by the City Council, one member going out of office each year. This Board takes cognizance of all matters affecting public health, regulates noxious trades, abates nuisances, appoints the city physician, quarantine officers, and superintendent of health, and requires that the scavenging shall be done to its satisfaction.

The system has worked well. The committee, unable to become familiar with the work during their brief term of office, of necessity content themselves with auditing accounts, and with such investigations and suggestions as they are qualified to make, and leave its management entirely to the superintendent; the Board of Health, for somewhat similiar reasons, appoint each year the same person to that office, and the superintendent, being supported by both bodies, is relieved from many petty attacks and annoyances incidental to a more autocratic position. Practically, therefore, the charge of city scavenging is in the hands of one man, the Superintendent of Health.

It is obvious that no operation of magnitude, and scavengering less than many others, can be efficiently carried on except by those accustomed to it; and that it is well done at Boston, is due almost entirely to the fact that it is in charge of men fitted by long training for its performance. The superintendent has filled his place for twenty years, and graduated from an inferior position in the work; all of the foremen, twelve in number, have been promoted from subordinate positions; few of the labourers have been less than five years connected with the department, many have served for twenty, a few for thirty or even forty years. Although the rate of wages is not especially high, ranging from forty-five to fifty dollars a month, the permanency of the employment causes places upon the force to be eagerly sought for, and when a vacancy occurs, there are many applicants to choose from. A young able-bodied married man is usually selected. His first instructions are, "Mind your own business; do your work to the best of your ability; don't talk politics; don't talk religion." The men know that a faithful discharge of their duties will ensure continued employment, and may lead to promotion. Rarely is one found to neglect his duties.

Scavenging in Boston comprehensively includes the following items :—

Removal of house offal.

Removal of ashes and dry house dirt.

Cleaning of streets and street catch-basins.

Cleaning of privy-vaults and cesspools.

Offal, which includes refuse food and other fragments of moist organic matter, known otherwise as swill, is taken every day from hotels, restaurants, boarding-houses, markets and other places furnishing large quantities of it, and three times a week in summer, and twice a week in winter, from dwelling-houses. At about 4 o'clock A.M., men leave the department yards, of which there are four in different sections of the city. Each gang consists of a horse, waggon, driver and helper. The horses are handsome, well-grown beasts, weighing about 1,400 lbs., and come generally from Pennsylvania. The waggons, built by the city, which also employs 11 mechanics to do its own repairing, blacksmithing, painting, &c., are perfectly water-tight, hold from 3 to 4 cord-feet, and have a wooden cover or lid, which is kept closed, except when raised to receive the offal. They cost to build £52 each. Hanging below them are two large wooden buckets to be used by the men. Hotels and markets are first visited, so that the offal may be removed before early travellers and customers begin to arrive. Shortly after 7 o'clock, dwelling-houses are visited. Midway between the streets, in most parts of the city, there are narrow alleys upon which the rear of house lots abut, and through these the waggons drive, the driver or the helper rings the bell at the yard gate, or at the basement door, if there be no yard, and, on being admitted, quietly goes to the swill-tub, empties its contents into the bucket, replaces the tub, and leaving the house passes to the next one, and so on until his bucket is filled, when it is emptied into the cart. Should no offal be found at any house, it is assumed that it has been improperly disposed of, and the case is reported to the Board of Health for investigation. These operations proceed till 11 A.M., and from 1 to 5 P.M.

When the waggon is filled, it is driven to one of three department depôts in the city, and its contents dumped upon a raised platform. The waggon is then thoroughly washed with water and scrubbed clean before going upon another trip. It is required that all the offal collected in a day shall be disposed of before night. There is no lack of regular customers for it, who drive in from the suburbs and neighboaring towns. These men back their waggons under a shoot in the platform, and a full load is shovelled into them. The cubic contents of each waggon is known, so that proper charges can be made. These range from 4*s.* 2*d.* to 5*s.* 10*d.* per cubic yard, varying according to the accessibility of the depôts to the neighbouring farms. The waggons are required to be water-tight, and each has a number in plain figures, two inches long, so that it can be reported by the police in case of leakage or any other offence while passing through the streets. From the sale of offal in 1878 was realised the sum of £5564. During the same time 26,000 loads were collected at a cost for labour of £11,270, to which must be added £4000 for the total cost of removal. Ninety-six men and forty-five waggons are employed upon this branch of the work.

While the city claims the right to remove all offal, or, what amounts to the same thing, refuses to license any private individuals to carry it through the streets, a wise discretion is used in exercising the right. Farmers and others living in sparsely settled districts on the outskirts of the city limits, occasionally wish to use their own swill for feeding swine, and when this can be done without creating any nuisance it is considered proper and economical to permit it. This discretion is left with the superintendent.

For the removal of ashes and house-dirt 117 men and 58 single-horse carts are employed. The carts are built at a cost of about £26 each. Hotels, stores, and tenement houses are visited twice a week, and dwelling-houses once. The driver and his helper enter the house, yard or shed, carry out the ash-receiver, and, after emptying the ashes into the cart, which has a canvas cover, return the receiver to its proper place. The men are not required to go up-stairs; and the ashes from tenements, and up-stairs offices and ware-rooms must be brought to the ground floor by the tenants. In dwelling-houses, the inmates have no trouble whatever. In most, if not all other cities, ashes, and often offal as well, have to be placed on the sidewalk to await the arrival of the scavengers, and, after being emptied, the receptacles are left where found. The Boston method is evidently a great convenience to householders. By it also is avoided the nuisance to foot-passengers of having to pass upon the sidewalk unsightly and offensive vessels or heaps of refuse awaiting removal.

When the cart is filled, the canvas is fastened securely over its contents, and the driver takes it to the nearest dumping-ground. In the mean time the helper, in order to expedite the work, continues to bring out ash-barrels so that they may be in readiness when the cart returns.

It is somewhat difficult to find accessible places for dumping the ashes; it may be doubted if it is possible to find unobjectionable places. A large part of Boston being very low land, there is great temptation to use this refuse in the place of earth filling; and such is its usual disposition. If the ashes were perfectly free from admixture with other substances, it would form suitable filling for most purposes, but it is not so. Although it is intended by the Health Department that only ashes shall be put in the ash-barrels, no rule to that effect can be enforced. By requiring that there shall always be at each dwelling a receptacle for offal, and by refusing to remove ashes with which offal has been mixed, that species of filth is in a measure kept out of the ash-barrel; an attempt is also made to keep out such substances as go under the general name of rubbish, by providing other ways of removing them.

Every spring, at ordinary house-cleaning time, it is advertised in the newspapers that during a certain week the carts of the Health Department will carry away from dwellings any rubbish or house dirt that the inmates desire to get rid of. A printed notice is also left at every house, specifying the day on which it will be visited. This is good, so far as it goes ; but the trouble is that such rubbish is constantly accumulating and cannot be kept till the next spring. When a bottle is broken, an oyster or preserve can emptied, a piece of matting worn out, or a pair of boots discarded, it is desired to be rid of them at once ; and in the heart of a city there is no way to get rid of anything except viâ the ash-barrel. On an average fully one-third of each cartload of so-called ashes consists of other refuse.

Portions of this refuse are harmless enough, as for instance, broken glass and crockery, plaster, old iron, and tin-ware, but other portions entirely destroy its suitability for filling, such as bones, hair, leather, rubber, paper, pieces of cloth or carpeting, old baskets, and in short, any vegetable or animal matters liable to decompose. Nearly all small animals that die in the city find a grave in the ash-barrel. How else can they be disposed of? There are not enough of them to deal with separately, and if they are thrown into the streets at night, they must be picked up by the first ash-cart and buried at the dump.

The ashes and house dirt are used to level up streets and parks belonging to the city, and private lands when desired or permitted by the owner. In a few cases a small sum is paid to the city for the filling. It is evident that the presence of the refuse house-dirt renders the ashes undesirable for street-building, for the mass as a whole compacts very slowly and continues to settle for years. If the surface be paved or covered with gravel, there will probably be no smell ; but digging trenches for laying gas and water pipes, sewers and drains, will be an offensive operation for a number of years, since organic matters kept from a free supply of oxygen decompose slowly. The use of such filling for grading open squares and pleasure grounds is not especially objectionable, except as it may cause offence while being deposited. To support vegetation it must be covered several feet deep with earth and loam, and the trees and plants quickly assimilate and destroy the products of decay. Frequent nuisances have been created by attempts to fill park lands on the borders of the sea. Salt water attacks the refuse matters and liberates foul-smelling gases. Enough sulphuretted hydrogen has been generated from half an acre of dumping-ground to discolour in a few hours the white paint of all the neighbouring houses.

Excavations made in Boston in land filled from city carts ten years previously have disclosed remnants of organic matter and the process of decomposition still going on. The cost of labour in removing ashes and house dirt during the year amounted to £20,300. Fully two hundred people find a livelihood by spending the day at the different dumping-grounds, raking over the loads of dirt as they are dumped from the carts, and collecting in bags and baskets such portions as can be sold to junk dealers.

Large animals, such as horses and cows, are disposed of by a contractor, who removes them for the privilege of possessing the carcase. When such an animal dies, the police send word to the Health Department, and the contractor at once despatches a cart for the body. It is taken to an island in the harbour, where every portion, it is said, is utilized, and the operation is very remunerative. It should be so, for it is also very offensive, and proper precautions not being used, the stench arising from it is carried by certain winds three miles to the city.

One hundred and eighty-five miles of paved streets are swept and cleared each week, some daily, others twice a week. Macadamized streets are not swept, as it is considered by sweeping off sand and detritus their durability is much lessened ; but their gutters are cleaned as required, and rubbish is picked up. The work is all done by daylight. Streets are watered before sweeping by six watering-carts. The dirt is swept to the gutters by men with birch brooms, and is thence shovelled into carts. Thirty men in all are thus employed. There are besides, in use, nine one-horse sweeping machines, having a revolving brush, each doing the work of eight men and at less cost, but they cannot clean corners and depressions as brooms can. One hundred and seventy men in all, of whom eighty-two are sweepers, are employed in cleansing the streets. Asphalte is most easily cleaned; next, granite pavement. During the year, 48,059 cartloads of dirt, of 40 cubic feet each, were collected and disposed of to fill land for streets, parks, and dwelling lots. Occasionally a load is of a sufficient manurial value to be sold for a small sum. The street refuse is uniformly composed of earth, road detritus, fragments of wood, leaves, paper, soot, hair, &c. It is manifestly an unfit substance for filling, but what also to do with it is a problem yet unsolved. The cost of street cleansing during the year amounted to £17,346.

For cleaning street catch-basins, forty-three men and fourteen waggons are employed. The sludge is hoisted by means of buckets and deposited in close covered wagons, in which it is carried to the dumping-ground and covered with ashes. Last year 8766 loads were collected at a cost of £2700. The sludge has absolutely no value. Vaults and cesspools, from five to six thousand in number, are cleared by contract by means of odourless excavators, at a charge of from 25*s.* to 33*s.* per load of 80 cubic feet, paid for by the householders. The excavators are air-tight, and draw the contents of the vault by the suctional force of a vacuum. The gases are destroyed by passing through a charcoal furnace as they are pumped out. Not more than one load in ten can be sold for manure.

In conclusion, it may be taken that the scavengering of Boston is, upon the whole, satisfactory. Sufficient money, amounting in 1878 to about £71,000 is appropriated for the purpose, and is well and efficiently laid out. The labourers do their work well, being used to it, and knowing that faithful work ensures continued employment, the removal and disposal of offal is satisfactorily performed. The removal of ashes, house-refuse, street-sweepings, and catch-basin sludge is satisfactory, but the disposal of these matters is not satisfactory. It is experienced that certain portions of city scavengering may be satisfactorily performed by contract, under good regulations, strictly enforced.

SCAVENGERING IN CALCUTTA.

The house-refuse has been by long-prevailing custom deposited in the streets at all hours. The obvious inconvenience of this practice led, in 1881, to the restriction of the time during which house-refuse may be deposited in the streets, from 12 A.M. (midnight) to 7 A.M. The carts commence removing refuse at 5 A.M. To those who desire it, the corporation provide corrugated iron dust-bins, of 12½ cubic feet or 16 cubic feet of capacity, at a charge of 18*s*. or 22*s*. respectively, with a little extra for brick-work stands.

The house-refuse with the road-scrapings and sweepings are conveyed out of town by the Municipal Railway to the Salt Water Lakes, where a square mile of area has been enclosed and reclaimed for the reception of all refuse. During dry weather this work is under complete control, and easy of performance; the unloading of the waggons and the levelling of the refuse can be and are carried on simultaneously, and what is of no little importance to the coolies, the work can be done in a comparatively leisurely manner without compromising the efficiency or conservancy of the town; the refuse is dry, light, and comparatively free from smell, and coolies may be had in any numbers. A few days' rain, however, is sufficient to alter the aspect of affairs altogether. The refuse suddenly increases in bulk and in weight; every waggon is in requisition at the town-platforms, and pressure has to be put on the coolies at their ultimate destination to unload them quickly. The coolies have then to work to the utmost of their strength without a moment's respite, and their discomfort is further increased by the heat of the fermenting refuse, which is not unfrequently so great as to make it impossible for them to walk on it. As a natural result, the refuse is carried a few feet only away from the waggons, and there thrown down and left to be picked up and carried out to contract distance when the weather is dry again. These drawbacks appear in their most intense form during the rainy season, when the quantity of refuse reaches a maximum which never varies, while the condition of the refuse, when it arrives at the lakes, makes it increasingly difficult from day to day to handle it.

In the waggons the refuse is steaming hot ; under foot it is sodden, and the coolies sink into it knee-deep, and, though inured to bad smells as they necessarily are, they find the stench gradually becoming unbearable. It is thus not surprising that the coolies fall ill, and eventually desert in large numbers for better work, and those who remain have to be bribed to do so by higher wages and all kinds of indulgences.

At this juncture the idea of carrying sweepings to a distance has altogether to be abandoned, and the raking of the stuff out of the waggons and clear of the rails is all the coolies can be got to do. This goes on fairly well until the heaps of refuse thus raked out of the waggons become too high at every point of the line, and then a collapse is sure to be the result. Utter collapse has barely been prevented by the provision of three new branch lines, an extra length of rails in extension of the channel embankment line, and the running of night trains. Great strain has been put upon all the powers of the establishment, intensified by the apprehension of fatal disorder in the town.

The cultivation of the land reclaimed by the deposit of sweepings at the Salt Water .Lakes is done by contract. All the conditions of soil and manurial strength are excellent. The cultivation during the early part of the year was limited to the growing of various kinds of oil-seeds and indigenous vegetables on the raised land, and the carrying out of surface improvements, such as the levelling of the land, and the picking out of potsherds, stones, and the like hard matter from the soil. During the rains the high lands yielded abundant crops of reana and impey, cucumbers, beet-root, carrots, ground-nuts and numerous varieties of " saugh." The nursery of fruit-trees flourished, but required close fencing and vigilant watching to protect it from the inroads of the wild pigs and scavenger birds with which the locality abounds. The favourable result of his experimental efforts in regard to the cultivation of potatoes, yams, and the widely used indigenous tuber known as "notashah" induced the lessee to risk their cultivation on a larger scale, only to invite wholesale destruction by rats underground, and by birds and wild beasts above ground. Tobacco has also proved a failure; for, although the leaves grew very large, they were without strength. The lessee attributes this rank growth to the over-stimulating character of the newly-formed soil, and confidently looks forward to better results in future years when the soil will have had time to mellow.

The annually increasing quantity of refuse removed from Calcutta to Salt Water Lakes is evidenced by the following for four years :—

	Waggon-loads.
1878	7,284
1879	8,011
1880	10,016
1881	11,197

Besides the 11,197 waggon-loads of refuse, weighing 73,000 tons, conveyed in 1881, 550 tons of offal from slaughter-houses were also conveyed.

APPENDIX A.

Commissioners &c. may appoint scavengers.

59. And be it further enacted, that it shall be lawful for the commissioners, trustees, or any other persons having the control of the pavements in the streets, or public places in any parochial or other district within the jurisdiction of this Act, and who by any local Act or Acts of Parliament relating thereto are also authorized and empowered to direct the cleansing of the streets or public places, within such parochial or other district, at any time or times hereafter, to agree by private contract or by public auction, or by tender or proposal if they shall think fit, for any time not exceeding three years, with any person or persons to be the scavenger or scavengers, raker or rakers, cleanser or cleansers of the streets and public places within the said parochial or other district, and such person or persons, on a certain day in every week, and oftener when thereunto required by any three or more of the said commissioners or trustees, or other persons as aforesaid, or by the surveyor of the pavements of such parochial or other district, or any inspector or other officer or person appointed by them or any of them, shall bring or cause to be brought convenient carriages into all such streets or public places where such carriages can be drawn near or pass unto and at or before their approach, by bell, horn, clapper, or otherwise by a loud noise or cry, shall give notice to the inhabitants, and shall give the like notice in every other place into which the said carriages cannot pass and abide, and such scavengers, rakers, or cleansers shall take and carry away, or cause to be taken and carried away, from the respective houses and premises of the inhabitants or occupiers, their soil, ashes, cinders, rubbish, dust, dirt, and filth, and all which the said scavengers, rakers, or cleansers shall carry away or cause to be carried away at their own cost and charges, upon pain of forfeiting a sum of 40*s.* for every neglect or default (except nevertheless all such rubbish, earth, dust, and filth as shall be

occasioned by building, repairing, amending, or altering any house or houses, or any other building or buildings, or by cleansing or repairing any drain or sewer) and also that the said rubbish, earth, dust, or soil, thereby occasioned, and every part thereof, within the space of twelve hours after the same or any part thereof shall be first left or placed in any street or public place, shall be carried away by or at the charge of the owner or owners, occupier or occupiers of such houses and buildings, or by the commissioners of such sewers respectively as aforesaid, and that such owners, or occupiers, or commissioners neglecting to remove the same, and every part thereof, or to cause the same to be removed within the time above limited, shall forfeit and pay the sum of £5 for every neglect to remove the same within the time above limited; and also that if any person or persons shall refuse to permit such other soil, ashes, cinders, rubbish, dust, dirt, or filth to be taken away by the scavengers, rakers, or cleansers, or other persons appointed by and agreeing with the said commissioners or trustees, or other persons as aforesaid, then every such person or persons so offending shall in like manner forfeit and shall pay the like sum of £5. Provided always, that it shall and may be lawful to and for the said commissioners, trustees, or other persons having the control as aforesaid, either to contract and agree with and to appoint the same person or persons, or a different person and other persons, to be the scavengers, rakers, or cleansers within their parochial or other district, of the streets or public places therein, and to be the persons to collect and carry away and possess and retain the soil, ashes, cinders, rubbish, dust, dirt, and filth from the houses and premises within their respective parochial or other districts, as they shall deem most expedient; but that the right and benefit of such soil, ashes, cinders, rubbish, dust dirt, and filth shall belong exclusively to the person or persons who shall be from time to time by the said commissioners or trustees, or other person as aforesaid appointed to collect and possess the same; anything in any local Act or Acts of Parliament or in this Act to the contrary, notwithstanding.

Dust to be removed only by scavengers so appointed.

60. And be it further enacted, that if any person or persons, other than the scavengers, rakers, or cleansers of any parochial or other district, or the other person or persons employed or appointed by or contracting with the said commissioners or trustees, or other persons as aforesaid to collect and retain the dust, cinders, or ashes within their respective parochial or other district, or those employed by and under such person or persons,

shall on any pretence whatsoever go about to collect or gather, or shall ask for, receive, or carry away any dust, cinders, or ashes,* it shall and may be lawful for any justice of the peace for the city, borough, or county within which such parochial or other district may be situate, upon complaint to him made, to grant a warrant to bring before him such offender or offenders, and also for any person or persons who shall see any such offence committed to seize, and also for any other person or persons to assist in seizing the offender or offenders, together with the horses, asses, cattle, carts, trucks, wheelbarrows, or other carriages, or implements made use of for carrying the same away; and by the authority of this Act and without any other warrant, to convey him, her, or them before such justice of the peace, or any justice of the peace for the said city, borough, or county; and such justice shall, and he is hereby authorised and required to examine upon oath the person or persons apprehending such offender, or offenders, and any witness or witnesses who shall appear to give information or evidence touching such offence; and if the party or parties shall be convicted of going about to collect or gather, or of asking for, receiving, or carrying away any dust, cinders, or ashes from any house or other premises within any parochial or other district within the jurisdiction of this Act, not being the person or persons employed or appointed by or contracting with the said commissioners or trustees, or other persons having the control of the pavements within such parochial or other district to collect and possess the dust, cinders, and ashes from the houses and premises therein, or not acting with or under his or their authority, he, she, or they shall respectively, for the first offence, forfeit and pay the sum of £10; for the second offence the sum of £15; and for the third and every subsequent offence, the sum of £20; and one moiety of which respective penalties shall be paid to the informer or informers, or to the person or persons who shall apprehend the offender or offenders, and the other moiety shall be paid and shall belong to the person or persons so employed or appointed by or contracting with the said commissioners or trustees or other persons as aforesaid, and if such offender or offenders shall not on conviction pay the said penalty or penalties, such justice is hereby required to direct such horses, asses, cattle, carts, trucks, wheelbarrows, or other carriages or implements which shall have been so seized, to be appraised and sold; and after deducting out of the moneys to arise by such sale the penalty or penalties incurred, together with the reasonable charges and expenses of such warrant, and of such distress, appraisement and sale, the overplus thereof shall be returned upon demand to the party or parties whose horses or other things shall be appraised and sold; and in case there shall have been no seizure as aforesaid, or if the horses, asses, cattle, carts, or other things which shall be appraised and sold shall not produce a sufficient sum of money to pay the said penalty or penalties, charges, and expenses, then if such offender or offenders shall not upon the conviction pay the said penalty or penalties, or such part or parts of the said penalty or penalties, charges and expenses which shall remain over and above the produce of the horses, asses, cattle, carts, and other things so seized and sold, then such justice is hereby required to commit such offender or offenders to the common gaol or house of correction for the city, borough, or county where such parochial or other district shall be situate, there to be kept to hard labour for any time not exceeding thirty days, unless such penalty or penalties, and charges and expenses, and every part thereof, shall be sooner paid and satisfied.

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* Ashes from a brass founder's furnace containing particles of metal, not "dust, cinders, or ashes" within this section, Law *v.* Dodd, 17 L.J. M.C. 65.

On the neglect of scavengers to remove dust for seven days, the dust may be removed by any other person.

61. And be it further enacted, that in case such person or persons so employed or appointed by or contracting with the said commissioners or trustees or other persons for the purposes aforesaid, shall neglect for the space of seven days to bring or cause to be brought carts or proper carriages into all the streets or public places as aforesaid where such carriages can pass, and to give notice in manner aforesaid to the inhabitants of their coming, for the purpose of taking away such dust, dirt, soil, rubbish, filth, cinders, and ashes, and to give the like notice in every place into which the said carts and carriages cannot pass, or to take away and remove all such dust, dirt, soil, rubbish, filth, or cinders, or ashes from the houses and premises of all and every the inhabitants of such streets or public places, or from such part or parts of such houses or premises where such dust, dirt, soil, rubbish, filth, cinders, and ashes shall be deposited, that then (after twenty-four hours' notice given to such person or persons so employed or appointed by or contracting with the said commissioners or trustees or other persons for the purposes aforesaid, or left for him or them at his or their usual house or houses, yard or other premises, requiring him or them to bring or cause to be brought carts or carriages to take away their dust, dirt, filth,

cinders, or ashes, and to take away and remove the same from their respective houses and premises), it shall and may be lawful for such of the inhabitants of such of the said streets or public places, who shall have given such notice as aforesaid, to give away or to sell their dust, dirt, filth, cinders, or ashes to any person or persons whomsoever; and that such person or persons who shall take and carry away the said dust, dirt, filth, cinders, or ashes, shall not be subject or liable to any penalty or penalties for so doing upon every such neglect; anything in this Act or in any local Act or Acts of Parliament contained to the contrary thereof notwithstanding.

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